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ELECTRICAL SECTION.

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Electrical Measuring Instruments.

BY CARYL D. HASKINS.

In selecting for the title of my paper so vague a term as "Electrical Measuring Instruments," I am quite aware that almost anything might be expected of me. Webster, I believe, defines the term "instrument" as a tool or implement. The selection of the word instrument, with its very vague literal meaning, for use in connection with a very concrete and definite class of electrical apparatus, is regrettable, but doubtless now beyond correction.

In electrical engineering practice the term "instrument" has come to mean very definitely all of that large group of devices which serve to indicate at any time the definite value in the desired unit of some electrical phenomenon. In short, the generic term "instrument" has been narrowed almost to a specific term, from sheer necessity resulting

from the paucity of our language as applied to our own particular art. In 1890 the term "electrical instrument" was indiscriminately used as applicable to an integrating meter, a curve-drawing meter, an indicating instrument, and even a magneto. To-day common commercial usage, which is always impatient of long titles for common things, has so narrowed the practical application of the term "instrument" as to almost literally confine it to those devices which indicate with a needle or the equivalent the value of what is under measurement. In the laboratory and among pure scientists the term has not been reduced to this specific meaning, and is still used and probably always will be used in its more generic sense, and as applicable to devices which the practical central station electrical engineer would scarcely recognize as coming within the scope of the term, even if broadly construed.

My paper to-night is devoted to that class of instruments which we may term *working instruments;* that is, those which are used in daily practice, and not so much for testing purposes as for purposes of frequent observation and indication of conditions. Such instruments, in short, as are used upon switchboards, or are carried from place to place for the purpose of making a large number of daily observations.

It is not my purpose to deal with the primary standards of measurement, even remotely. Nor do I intend to deal with the secondary or bench standards which are used in comparing, checking and calibrating the working instruments.

There are two natural divisions of the electro-dynamic art, which separate instruments into two general classes—those suitable for use upon continuous current circuits only, and those for use upon alternating currents, this latter class being quite commonly capable of use upon continuous current also, with at least fair accuracy.

With instruments of position, which are by far the most important group commercially, and are used by thousands where portable instruments are used by hundreds, the design is of necessity governed by a number of essential qualities necessary to make an instrument practical and serviceable for constant use.

Passing over accuracy as an obvious necessity, we find that the quality of at least next importance is that of *permanence.* This means that the successful instrument must consist of elements unlikely to change either temporarily, on account of outside influence, or permanently, because of internal derangement.

This characteristic naturally implies indifference to external influences, as, for instance, the effects of stray fields, or of temperature.

For most applications, instruments of position must be highly "dead beat." This is an unfortunate term and I dislike to use it. It appears, however, to have no synonym. An instrument, however accurate, having a needle which vibrates and swings under fluctuating loads so constantly as to practically never come to rest is well-nigh valueless for most practical applications. It is, therefore, important that instruments for all such applications should be so designed as to cause the needle to come quickly and definitely to rest, and this must be accomplished without resorting to means likely to impair its sensibility.

For example, an instrument may be made to come quickly to rest by merely increasing the friction of the moving parts, but obviously such a means of achieving the desired purpose is highly detrimental, unless indeed the friction be applied only at will and intermittently.

On the other hand, the use of a damping structure, dependent upon the generation of foucault currents in a moving disc or sector, passing across the field of a magnet, is well-nigh ideal, involving as it does substantially no increase of friction and yet effectively checking vibration.

Finally, in instruments of position, the length, legibility and distribution of the scale is of great importance.

There is a considerable variance of opinion among electrical engineers as to the preferable scale distribution. An evenly divided scale, showing the same linear deflection of the needle for any given value throughout the entire scale length, has been quite commonly preferred, and this was especially true in the earlier state of the art.

On the other hand, to-day, preference naturally and I

think logically trends towards a maximum scale length through that portion of the scale likely to be most commonly used.

To illustrate: an ammeter used in measuring the current from a single generator of say 500 amperes rated capacity is seldom referred to to ascertain definite values below 250 amperes. Hence, it is the area between 250 amperes and

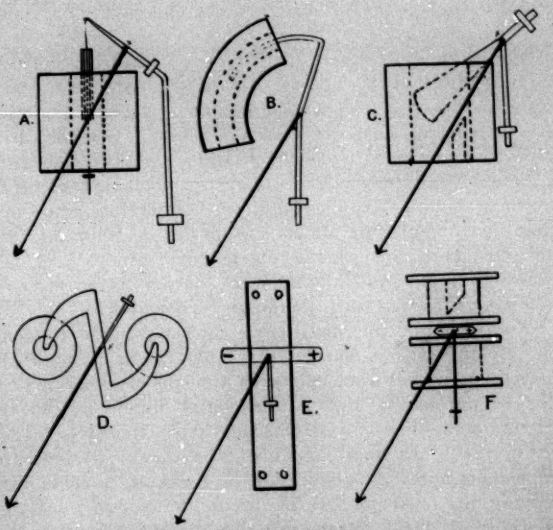


PLATE I.

full scale that is of the greatest value, and this area should be large in relation to the scale area below the half-load value of the machine. It is true, that the lower portion of the scale may be required at times, but close measurements at these low points are rarely needed and narrow divisions imply nothing undesirable.

Having outlined a few of the more important requirements for instruments of position, I propose to lay before

you some of the elementary principles which have been resorted to in the art of instrument design.

Before outlining these various principles I wish to remind you that the designer, surrounded as he is by the most sordid of commercial considerations, has generally conspicuously before him not only the essential characteristics which I have mentioned, but also the more irksome ones, which prescribe that the product of his ingenuity must be cheap, easy of manufacture and capable of shipment for long distances by the common means of transportation, with a fair prospect of arriving at its destination in a workable condition.

The various principles which have been resorted to in designing instruments of the class with which I am dealing may be grouped as follows:

(1) *Modifications of the mariner's compass*, or simple galvanometers, consisting of a polarized movable element under the influence of a coil or coils, carrying the current to be measured. This is the earliest group. Plate I, *Fig. E.*

(2) *Solenoids.*—Dependent upon the pull of a coil or coils on an iron plug or armature acting against gravity, a spring, or other restraining force. Plate I, *Figs. A, B, C, D, F.*

(3) *Magnetic repulsion instruments having iron*, consisting of a movable and a fixed piece of soft iron, both situated in the same field, consisting of a coil or coils carrying the current to be measured. Both pieces of iron being polarized in the same direction tend to repel each other, this force acting, as in all of the instruments in the mechanical group, against some restraining force. Plate II, *Fig. B.*

(4) *Magnetic Vane Instruments.*—Consisting of a vane or armature of soft iron, constituting the moving element, and placed within the influence of a coil or coils carrying the current to be measured. The normal position of the magnetic vane at no load is across the magnetic path created by the current in the coil or coils, the tendency being for the vane to place itself parallel with, or in some cases to surround the field created by, the passage of current through the coil. Plate II, *Figs. A, FF.*

(5) *A fixed and a movable coil or coils*, sometimes with, but

generally without iron — a development of the Siemens dynamometer. The movable coil tends to place itself either at right angles to, or in the same plane with, the fixed coil, depending upon the relative direction of current in the two coils. This principle may obviously be modified to provide for one fixed coil repelling and another fixed coil attracting a movable coil. Plate II, *Figs. H, D.*

(6) *A movable coil, with or without iron, situated in the field of a magnet,* the movable coil tending to take a position at

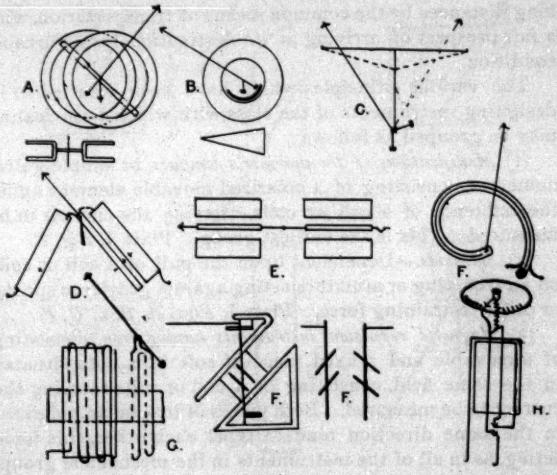


PLATE II.

right angles to, or parallel with, the flux of the permanent magnet, depending upon the direction of current in the moving coil — a development of the D'Arsonval galvanometer. Plate III, *Figs. B, C, D, E.*

(7) *A movable coil or conductor,* commonly with a small number of turns and frequently consisting of a disc or sector instead of a coil, constituting a short-circuited secondary in the field of a coil or coils carrying the current to be measured. This device is operative on alternating current

only. The movable short-circuited coil or sector tends to move in relation to the fixed field exerting force in opposition to the restraining force of a spring or gravity. Plate II, *Fig. G.*

These classes (groups 1 to 7 inclusive) constitute what might be termed the Dynamic Group.

It will be noted that of these, four groups (1 to 4 inclusive) consist of instruments having a moving element carrying no current, and are therefore free from conductors. Groups 5, 6 and 7 have moving wire-carrying current, necessitating the introduction of flexible conductors or collectors.

We now come to a series of somewhat indefinite groups, which may be broadly classed as *temperature instruments*, in which the position of the needle or indicator is governed by a change of temperature; in short, *thermometers* applied to electrical measurement by resorting to structures, the temperature of whose governing parts will vary with the current to be measured. There are in this general class the following groups, which unfortunately are less well defined than the genera of the dynamic group:

(8) *A thermometer surrounded by a conductor whose temperature varies with the current*, the scale of the thermometer being graduated to indicate the current causing any given temperature. Such instruments, in common with most of this class, are dependent upon a fixed room temperature, unless a correcting constant or means for mechanical correction be provided. Plate IV, *Fig. E.*

(9) Instruments in which the position of the needle is dependent upon the expansion or contraction of a conductor, due to changes of temperature in that conductor, caused by the current passing through it. Plate II, *Fig. C.* A well-known type of this group is the Cardew voltmeter.

(10) *Thermostats Provided with an Indicating Needle.*—The moving element consists either of a metallic and non-metallic substance, with differential coefficients of expansion, the metallic element carrying the current, or a moving element consisting of two metals of different coefficients of expansion connected in series, and carrying the current; Plate II, *Fig. F;* or a simple thermostat heated by radiation from a fixed coil, the moving element carrying no current.

There is one principle which has been used in electrical instruments which is more commonly seen in pure thermostats. It falls within the next group.

(11) *The development of pressure within a confined space*, due either to the expansion of gas or fluids under temperature-increases, or to the volatilizing of a fluid having a low boiling point. Plate IV, *Figs. C, D.* The generated pressure may either expand a diaphragm forming a portion of the walls of the receptacle retaining the gas or fluid, or may

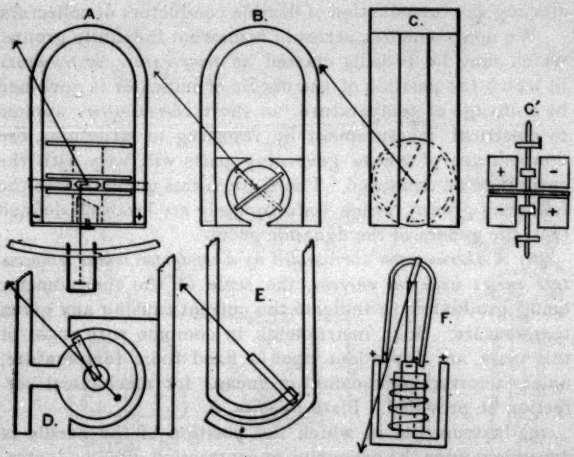


PLATE III.

cause the straightening of a bent tube containing a volatile fluid, or gas, as in a common form of thermostat. In the first form motion is communicated to the needle as in a steam-gage or an aneroid barometer. In the second form by the direct attachment of the needle to the bent tube.

There are other instruments falling within the thermal class, which hardly come within the scope of the definitions I have cited. They are unimportant and are intentionally omitted.

(12) *Electrostatic Instruments.*—These comprise a single family and genus. They consist of *practical applications of the electrometer* and several practical forms. Two or more plates are symmetrically arranged in two, or in some cases three groups. One group is attached to one pole of the system under measurement, and the second to the other pole. The moving element consists of a light metallic vane having *capacity* large in relation to its mass. The tendency of the moving vane is to place itself with its greatest length parallel to the shortest path between the plus and minus fixed plates. Another form has one or more fixed plates attached to one pole of the system to be measured, and a movable vane attached to the other pole. The tendency in such a structure is for the movable vane to place itself parallel with the shortest path between the fixed plate or plates and the point of attachment of the movable plate or plates.

Modifications of structures of this kind are used for the detection of grounds. When so used, three or more groups of plates are provided, the movable vane sometimes constituting one, whilst one group is connected to ground. With this arrangement a ground renders the permanently grounded plate and the newly grounded plate a common element, the movable element adjusting itself in position accordingly.

Instruments of this class are largely used for the measurement of very high potentials where the conducting of current through a coil, moving or otherwise, would be attended either with grave practical difficulties or with material physical danger to the structure or human life, or with an unnecessary expenditure of energy. Plate IV, *Figs. I, J.*

We now come to a class of instruments in which the actuating force of the needle is derived from an independent source, and its application to the moving element is only governed, either in volume or in period, by the current to be measured. We have in this class two general groups:

(13) *A source of air or fluid pressure, controlled in intensity by a valve;* for example, a reducing valve electrically controlled, a source of air or fluid pressure, and a pressure gage. Plate IV, *Fig. G.*

(14) *A Clock or the Equivalent Directly Connected to a Needle.*—In such a structure the clock is started by the current and drives the needle forward over the scale until the torque of a spring connected to the hand balances the coercive force of the measuring coil, at which point the relay contact is broken, causing the clock to stop with its needle upon the value reached. This device is a modification of the balance, and is practically a weighing machine. Unless still further

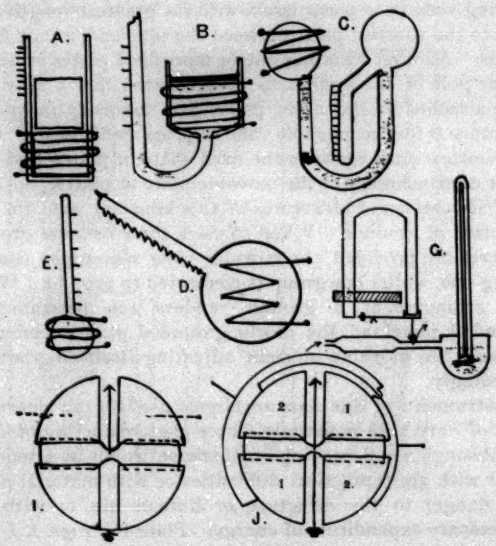


PLATE IV.

modified the needle remains upon the highest reading reached during use.

We now come to a class of instruments really used as *working instruments of position*, but very generally used for secondary or bench standards. These are balances, structurally incapable of indicating the desired measurement without manual manipulation. They are two general classes.

(15) Instruments in which a definite torque is produced by resorting to any of the structures heretofore described (but generally to a fixed and movable coil or coils). This torque is manually balanced by the winding up of a spring, as in Siemens dynamometer, or by the manual adjustment of a counterweight, as in the Kelvin balance—the position of the needle attached to the spring manually wound, or the position of the weight manually adjusted being read. Such readings may be direct, but for convenience are more commonly arbitrary, and are multiplied by a known constant. Plate II, *Figs. H, E.*

(16) Instruments designed to be brought to zero used in conjunction with a Wheatstone bridge.

It is possible that in thus classifying the means which have been resorted to in the effort to produce indicating instruments, I may have treated my subject in too elementary a manner, and my excuse is, that I know of no paper, book, or essay, in which full classification has heretofore been attempted.

We now come to some mechanical considerations. First in importance (because most essential) is the means of communicating the motion of a moving element to a second element which shall move across the scale. Commonly this is achieved by the direct attachment of a needle to the moving element proper. This, however, is not the unvarying method. In the solenoid group, for example, we find a type of instrument in which the moving element (a plug of iron) floats on mercury within a glass receptacle, the iron being drawn down into the mercury by the current in the fixed coils, and the level of the displaced mercury in relation to its normal level being read. Plate IV, *Fig. A.* Similarly we find the thermometer stem not uncommonly used, the level of the fluid within the stem being governed by the pressure upon a diaphragm, or by temperature, the reading being taken as in the thermometer. Plate IV, *Fig. B.*

Sometimes the Scale is Moved in Relation to a Fixed Needle.—Deviations from the simple plan of attaching the needle direct to the moving element have commonly been resorted to in the effort to increase the angular movement of the

needle in relation to the angular movement of the moving element. Numerous mechanical multipliers have been used for this purpose, such as direct "gearing up," just as in a bicycle. Such mechanical modifications are of doubtful advisability. The coercive force of an instrument must always be relatively very small, and the introduction of friction, inseparable from any mechanical multiplier, is highly undesirable in any device where a small coercive force must be communicated with precision to an indicating element.

It is not my desire to condemn mechanical multipliers, but rather to call attention to the inherent difficulties incident to their use, introducing as they do a variable factor, difficult to so construct and adjust as to remain fixed in value.

It is, of course, highly desirable to secure the greatest possible angular deflection of the needle that can be achieved without introducing other detrimental characteristics. There are, however, other and perhaps better means of accomplishing this than by resorting to mechanical multipliers. An iron vane or a moving coil may be mounted eccentrically to a fixed coil in such a manner that the moving vane or coil in passing from the minimum to the maximum position in relation to the fixed coil must revolve its pivot or shaft through a large angle in relation to its plane. Plate II, *Fig. FF.*

It is proper that we should now consider the question of a restraining force.

Substantially all instruments within the groups with which I am dealing consist of a moving element, which, under any given coercive force, changes its position until the coercive force applied to it balances or equals the applied restraining force. This restraining force may be applied in several ways. Thus:

A spring may be used, as the hairspring of a watch, placed under torsion by the progress of the moving element.

The force of gravity may be utilized by the lifting of a weight, equivalent and in some respects superior to the spring. Plate I, *Figs. A, B, C, E, F.*

A magnetic field may be provided with an iron armature attached to the moving element, and so situated as to occupy the shortest magnetic path when the instrument is at zero, this restraining armature being dragged for a greater or less distance out of the restraining field by the coercive force of the instrument. Plate III, *Fig. A.*

These three methods of securing a suitable restraining force cover substantially all of the methods used in the construction of instruments, with the exception of thermal instruments, most of which seek their zero position because it is their normal static condition.

After the instrument-designer has selected the restraining method most suitable to the device under consideration, he must (if the instrument be of the class requiring dead-beat qualities) next consider how the vibration of the needle is to be checked without detriment to precision. This has been accomplished in numerous ways, all more or less effective.

(1) By application of friction. This method of damping is to be found, without intent on the part of the manufacturer, in all instruments having bad bearings.

It might be well to call attention at this point to the fact that the heavier the moving element the greater the friction, other things being equal; and also the greater the inertia and the greater the storage of energy in the moving mass. Hence, the heavy moving element is more difficult to make satisfactorily dead-beat than the lighter moving element.

Friction for the purpose of damping has been purposely applied in numerous instances, but generally only in the form of a brake, to be used at the discretion of the user.

(2) By the dash pot, which is a vane or piston moving through fluid, or a tight-fitting piston in an air cylinder like a door check.

(3) By a hollow cylinder, or more usually by a disc-shaped cylinder, partly filled with a somewhat viscuous fluid such as glycerine.

(4) By a simple disc-shaped cylinder containing one or more small spheres or balls acting in a manner almost

exactly similar to the viscous fluid, but without the objectionable tendency of the viscous fluid to adhere to the sides of the cylinder above normal level, thus changing the balance of the moving element.

(5) By means of air vanes moving in a more or less confined space. These are highly effective in checking the swing of light-moving systems, since such systems have a higher period vibration and, consequently, during vibration move more rapidly; and since the resistance to motion on the air fan increases as the square of its velocity, it will be seen that such fans can most efficiently be applied in connection with the damping of high speed vibrations.

(6) By the generation of foucault currents, which may generally be regarded as the better means of damping without the introduction of detrimental effects. This class of damping takes two forms:

A fixed metallic body, so placed that the movement of a magnetic body in juxtaposition to it shall generate foucault currents within its mass, as by the enclosing of a compass needle within a copper cylinder, the lines of force projected by the needle cutting the mass of the copper cylinder and generating foucault currents therein. Or, a disc or sector attached to the moving element and moving across a magnetic field, as described earlier in this paper.

The volume or intensity of current to be measured is in ordinary practice frequently so considerable as to make it highly undesirable and indeed practically impossible to bring the actual total current to be measured through the instrument. The cost of bringing the current to the instrument would in a large number of cases be prohibitive, even though other considerations rendered it permissible. This necessitates some ratio device. In connection with current measurements these ratio devices are of two kinds: one applicable to alternating current and the other to direct and sometimes to alternating current. The first of these ratio devices—that applicable to alternating current—is the current transformer, a simple transformer having a primary of extremely low potential, consisting of a small number of turns or even part of a turn, the primary being connected

in series with the line conducting the current to be measured. The secondary of this transformer is of a relatively large number of turns and a higher potential, and is short-circuited through an ammeter whose actual current capacity is small, but the scale of which is calibrated to read the current in the primary of the transformer. It should be understood that the potential of the secondary of the transformer, though referred to as relatively higher than the primary, is itself extremely low. It will be seen that the current in the secondary of the transformer will vary in a direct ratio with the current in the primary through the range of the transformer iron, and therefore the indication of the instrument varies in exact relation to the fluctuation of current in the primary. The introduction of a current transformer, therefore, not only obviates the necessity of conducting heavy leads to and from the instrument, and all that it implies, but also isolates the live portions of the instrument from the actual potential of the system, rendering the instrument harmless.

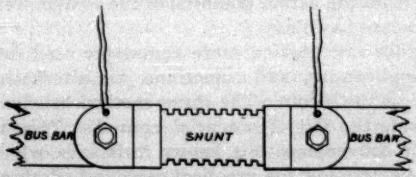
The other ratio device, more commonly used for direct current applications, and sometimes for alternating purposes also, is the shunt. The shunt method briefly consists in measuring the fall of potential around a known resistance. For convenience this known resistance, which must of course be very low for practical reasons, is designed as a separable portion of the conductor and is made from a metal of very low temperature coefficient. The shunt method, it will be noted, achieves the same desired purpose as does the current transformer, save that the live portions of the instrument are in this case electrically connected to the actual system under measurement. This, however, is entirely permissible, since this method is rarely if ever applied to systems of dangerous voltage.

For use in connection with volt-meters on high potential systems a second form of transformer known as potential transformer is very generally used. Like the current transformer this is a ratio device having a primary winding of a large number of turns attached across the system, the potential of which is to be measured, with a secondary winding

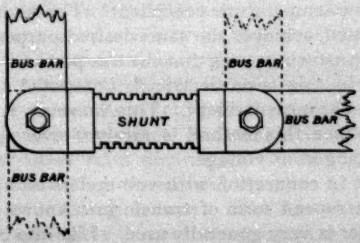
of a relatively low number of turns and impressing a relatively low potential upon the volt-meter to which it is electrically connected. As in the current transformer, the potential of the secondary varies in direct relation to the fluctuations of the primary potential. Volt-meters thus arranged are, however, not commonly calibrated in the potential of the primary, but rather in the secondary potential which prevails throughout the system served. In common with the current transformer the use of the potential transformer not only obviates the necessity of exercising extreme care in the insulation of the leads to and from the volt-meter, but also isolates the live portions of the volt-meter from the higher potential of the system.

Discussion.

Mr. Richard L. Binder inquired as to the relative accuracy of the shunt-type instruments and series-type



This arrangement gave one reading, and



this gave another reading; and on changing bus-bars to the various positions a different reading was recorded each time—about 500 ampères at 110 volts passing.

instruments, stating that in one instance with a shunt-type instrument he had noticed a variation in the readings depending on how the bus-bars were led into the shunt, and requesting information as to what caused this variation. The sketches accompanying will explain what was done at this experiment.

MR. HASKINS: There is no inherent difference in sensitiveness to stray field from bus-bars, etc.; between shunt-type ammeters and series-type ammeters. All indicating instruments which are not conducted on the astatic principle, or which have not some specific means for effectively shielding the moving parts against stray fields, are affected by neighboring bus-bars to some degree. In the case cited the errors undoubtedly resulted from the position of the bus-bar and leads, and were in no way related to the shunt.

MR. CARL HERING: In his interesting paper, Mr. Haskins objected to the term "dead-beat," and regretted that there was no better term in existence. I agree with him that the term is not a very desirable one, owing to its other meanings, although it originated, no doubt, from the fact that it meant that the beats or oscillations of the needle are deadened. He is, however, mistaken in saying that there is no other term, for the term "aperiodic" expresses precisely the same thing. It comes from two words, meaning that the needle then has no period of oscillation; that is, it does not oscillate like a pendulum. It does not mean that the needle is made so light and small that its natural period of oscillation, if free, is negligibly small, but, on the contrary, refers more to relatively large and heavy needles that would have a very decided period of oscillation if free. The word, therefore, does not refer to the natural period of oscillation if it were free, but simply means that, as used, the needle makes no or very few oscillations. The term is used in the German and French languages in a sense precisely the same as the one in which we use the objectionable term "dead-beat." I have been trying for years to help to introduce the word into this country, but with only moderate success. It would be well if experts became more familiar with it, and used it in the place of "dead-beat."

MR. HASKINS: I welcome Mr. Hering's suggestion of the adoption of the term "aperiodic" instead of "dead-beat" as a timely and appropriate one. I apprehend but two difficulties in the introduction of this term in American and English practice: (1) The fact that the term "dead-beat" has become universal, and (2) a certain literal difference of meaning, which in European practice has been entirely offset by custom. I share with Mr. Hering the hope that this word may be substituted in American practice for the term "dead-beat."

PROF. ARTHUR J. ROWLAND: We rarely have an opportunity to listen to one who has had so much to do with the development of modern electrical instruments as Mr. Haskins, or to ask him questions. When, therefore, I found that Mr. Haskins was going to present the paper we have been listening to before the Electrical Section, I made sure I must be present to hear it. I have been exceedingly interested in all that has been brought to our attention, but have in mind several matters which have not been touched upon, and I am going to take advantage of an opportunity to ask still other questions.

(1) What is the accuracy of an A.C. ammeter used with a series transformer as compared with the accuracy of the same instrument used straight in the A.C. circuit? For example, suppose I have an inclined coil Thompson ammeter, range 0–25 amperes, used to measure 20 amperes; and again with a series transformer of the ordinary commercial type having a transforming ratio of 10–1 used to measure 200 amperes. What relative accuracy of reading may be expected? Will the instrument make the second reading correctly by using a multiple of 10 for scale readings? Will the instrument measure 200 amperes with a less accuracy than 20 amperes?

(2) What is the accuracy of an A.C. wattmeter used with transformers in circuit of both the current and potential coils, as compared with the accuracy when used direct? For example, suppose I have an inclined coil Thompson wattmeter, range 2,500 watts, and I use this directly to measure the power in a circuit where 20 amperes at 100

volts is used; and again I use the same instrument with potential and current transformers, each having a ratio of 10–1 on a circuit carrying 200 amperes at 1,000 volts?

In both questions I have in mind commercial apparatus and commercial conditions, and ask them because the connection of A.C. instruments with transformers is so common now. Without thinking it out in detail, or making any experimental trial, it seems to me that in case of the wattmeter for example, not only will the accuracy of the instrument be affected by the regulation in the transformers used and by variation in frequency of the applied E.M.F., but some little also due to changed phase relations between current and E.M.F. after their transformation.

(3) How much will the accuracy of the wattmeter in question 2 be further affected by using the same current transformer not only for the wattmeter but for an ammeter and perhaps for a recording wattmeter as well? By interposing the other instruments in the circuit of the secondary of the series transformer the impedance of this circuit is considerably increased without increase of E.M.F. to get current through it.

Any information on these matters which Mr. Haskins may be ready to give will be highly appreciated.

MR. HASKINS: The character of Professor Rowland's first question is such that no specific answer can be made. The accuracy of an ammeter combined with a current transformer is not quite equal to the accuracy of the instrument alone, but the additional error introduced by the transformer may be so minute as to be entirely negligible. It is much dependent upon two conditions which I will explain.

It should be borne in mind that with a combination of ammeter and transformer we are dealing with the errors of two devices instead of one, and these errors may be cumulative or the opposite. If an individual ammeter is calibrated with an individual transformer, then the characteristic variations of ratio which may characterize that transformer are corrected in the scale calibration of the ammeter; but for practical reasons it is frequently desirable to utilize

ammeters and current transformers, which are interchangeable. Under these conditions the accuracy of the ammeter depends upon the uniformity of ratio of the transformers used. The ammeter may either be calibrated to correct the errors of ratio at different loads which characterize a whole line of transformers, and the transformers may be checked against this calibration standard; but if the transformer is to be used in connection with recording meters as well as indicating instruments, then the correction of ratio error in the transformer on the scale of the ammeter is not permissible, as similar corrections cannot be made in recording meters, and therefore, a current transformer having a substantially unvarying ratio through its useful range must be resorted to. In practice, a range of from one-tenth to full load is all that can be expected from a current transformer. This is unimportant, as it should be remembered that no indicating instrument ought to be regarded as accurate at loads of less than 25 per cent. of the maximum scale. The accuracy of a current transformer through the specified range is entirely dependent upon the proportioning of its parts, the character of the iron used and the portion of the saturation curve at which the iron is worked. It is obvious that iron in such transformers should be worked at low saturations, or through that portion of the iron curve where the lines per square inch increase in direct ratio to the increase of current in the primary.

The above, I think, answers both questions 1 and 2 propounded by Prof. Rowland. The answers cannot be made more specific, as the results obtained are entirely dependent upon the design and character of the current or potential transformer used. It is proper to point out, that the use of both current and potential transformers is prompted primarily by motives of safety and convenience, and their use is confined and should be confined to measurements in connection with high potential systems where it is undesirable to directly connect the instrument to the system, or to alternating systems of large current volume where a current transformer is used as a matter of convenience, sometimes almost of necessity, as is the case with the shunt in connection with direct current instruments.

It should also be pointed out that there are inherent errors in alternating current ammeters of very large current capacity, due to foucault currents and other similar causes, which, in connection with measurements of large current volume, render the results obtainable with a current transformer more generally reliable than those obtainable with an instrument connected direct.

Prof. Rowland is correct in assuming that the accuracy of a wattmeter will be affected by any errors of regulation in the transformer, and these errors of regulation must be eliminated by correct design.

Prof. Rowland is also correct in assuming that variations of frequency may similarly affect the instrument, but in a correctly designed current or potential transformer such errors may be so nearly eliminated as to be practically incapable of detection through the range to which such variations are commonly confined.

With reference to question 3. If the current transformer be designed to carry a load upon its secondary equivalent to the several instruments in series cited by Prof. Rowland, then the addition of these instruments to the secondary will not affect the wattmeter. It is customary in practice to so design current tranformers as to permit of a specific load, which may be made up of one or more instruments, the sum of which does not constitute a load exceeding certain ohmic or inductive resistance. This question also is entirely a question of correct transformer design.

THE ELECTRIC LIGHT IN EXAMINATION OF GEMS.

According to the *Electrical World and Engineer*, M. Chaumet, in Paris, has recently made some experiments with a view to the use of such rays in the determination of the value of gems. Becquerel ainé noted years ago the fluorescence of diamonds under the influence of various colored rays. Chaumet has ascertained that there is a close relationship between this fluorescent property and the brilliancy of diamonds under artificial light, particularly candlelight, which brings out most clearly the quality of first-class stones. Diamonds that sparkle most vividly are not always those cut in the most regular shape, but those showing the greatest amount of fluorescence when examined with violet light. While diamonds that are non-fluorescent when exposed to this light simply take a violet coloration, the most sparkling stones show a

notable fluorescence of a very luminous and clear blue. Diamonds, whatever their quality, always offer the same transparency to Röntgen rays, so that it is impossible to differentiate them by means of radiography. In a jewel-case in which are grouped diamonds of all qualities, the gems, when illuminated by violet light, assume different tints, some showing a vivid blue brillance, while others are of a sombre violet. As soon as the electric lamp is put out, all degrees of phosphorescence are noticeable, the jewel-case appearing to be studded with violet or blue glow-worms—some very bright, others almost extinct; and the most sparkling stone will be found to be the best. In the course of his experiments, M. Chaumet has observed a curious fact with respect to a yellow diamond with numerous facets which showed remarkable golden reflections in daylight as well as in artificial light. The violet light produced no fluorescence in this case, but gave rise in places to flashes of an intensely red color, particularly noticeable on the feather-edged sides. A violet pencil of rays was projected upon this yellow diamond for a few minutes, when the experimenter found to his surprise that the yellow color had changed to dark brown, the stone thus losing four-fifths of its commercial value, which, however, was recovered after some hours. In experimenting on the action of the various rays on rubies, M. Chaumet has ascertained that the Siamese stones are of scarcely appreciable fluorescence under violet light, while all the valuable Burmese rubies are intensely fluorescent, exhibiting a clear vivid red light that puts them in evidence when they are mixed with stones from Siam, which remain sombre.

NERNST LAMP GLOWER.

A defect of a solid Nernst lamp glower is its tendency to break down under currents of considerable volume, by reason of the central portion of the glower becoming fused by the current. In a patent issued December 30th to Henry Noel Potter, a glower is described which is designed to obviate this defect. The glower is in the form of a hollow tube, with the terminal wires twisted about the ends and covered with a pasty material similar in composition to that of the glower proper.—*Electrical World.*

DENSITY OF THE EARTH.

In order to determine the density of the earth, President F. W. McNair, of the Michigan College of Mines, and Major John F. Hayford, of the United States Coast and Geodetic Survey, will conduct experiments at the Tamarack Mine, which is particularly well fitted for this purpose, since its shaft is one of the deepest in the world, penetrating to a depth of 4,550 feet in strata of uniform density. The density of the earth is largely a matter of scientific conjecture. It has been computed by formulæ based on Newton's laws of gravitation. It is true that Sir George Biddle Airy, the British Astronomer Royal, computed the earth's density from experiments which he carried on at a Welsh colliery, but the figures which he obtained varied so much from those based on the formulæ that they have not been generally accepted.—*Scientific American.*

Section of Photography and Microscopy.

Read at the Joint Meeting held December 11, 1902.

Notes on the Water-Supply in Ancient Jerusalem.

By Henry Leffmann.

Information obtained in recent years indicates that Jerusalem was a strategic point in Palestine at an early period, but its importance as a metropolis was, as usual, of slow growth. For many centuries the city has been little more than a sacred memory. It received severe treatment at the hands of the Cæsars; the Emperor Hadrian, in the second century of the common era, destroyed it as far as he could and renamed the site. This attempt to efface the Holy City from the memory of man failed miserably, but the material evidences of its golden era were largely obliterated.

We know comparatively little of the ancient world, but one fact stands out in strong contrast to the conditions of medieval life, and even of many modern cities, namely, the care taken to secure a good water-supply. The highest honor for this sanitary measure is justly given to the city of Rome, but this was by no means the first. It is only of late years that the details of the water-supply of ancient Jerusalem have been unearthed. The following description is compiled from various recent sources.

Jerusalem is on high ground, and is surrounded by valleys. Its walls enclose a space of less size and population than some of the wards of Philadelphia. It is known that in some of the severe sieges, the inhabitants suffered most for want of food while the besieging armies suffered most for want of water. From this it is to be inferred that either springs existed in the city or that water was conveyed in concealed conduits. The latter view is now known to be correct; possibly the former is also.

It is believed by the authorities that the earliest efforts

at impounding natural waters so as to secure a constant supply for use at or near Jerusalem began in Solomon's time by the building of reservoirs in the Kedron Valley (east and southeast of the city) for the supply of water to the royal gardens. This reservoir, called by Josephus, Solomon's Pool, cannot now be found. Later an open channel

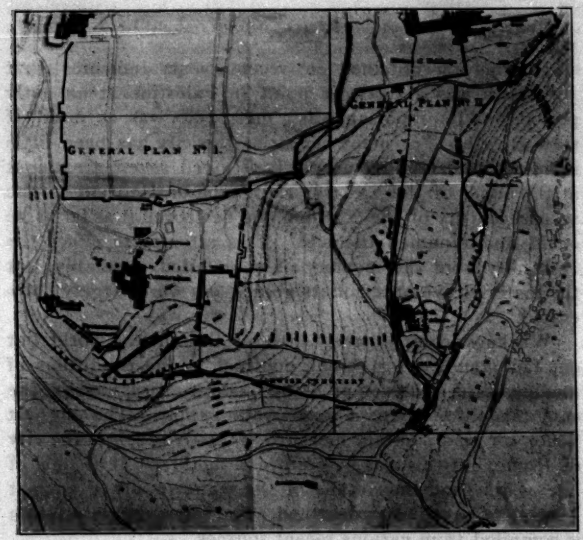


FIG. 1.—Map of Southern Jerusalem and adjacent districts. The tortuous aqueduct from the Virgin's Spring is seen on the right, in the Kedron Valley.

was cut in the rock forming the west slope of the Kedron Valley, by which the water was led to a point where it was easily available to the residents of the city. It has been suggested that the words of Isaiah, viii, 6, "the waters of Shiloh that go softly," are an allusion to the flow in this conduit which has but a slight grade. The original channel was identified in 1866. A more interesting and impos-

ing work was carried out some 300 years after Solomon's time by Hezekiah who, prior to the Assyrian invasion, impounded the water of a spring to the east of Jerusalem and brought it down to the east side of the city. This work is mentioned in both the accounts of Hezekiah's reign; thus, in II. Kings, xx, 20, we read: "Now the rest of the acts of Hezekiah and all his might, and how he made the pool and conduit and brought water into the city, are they not written in the book of the Chronicles of the kings of Judah?" Turning to II. Chronicles, xxxii, 30, we read that Hezekiah "stopped the upper spring of the waters of Gihon and brought them straight down on the west side of the City of David." Palestine archeologists regard Gihon as identical with a spring now just ouside the city wall and known as the Fountain of the Virgin. The operation of Hezekiah involved the construction of a tunnel through rock in a tortuous course of over 1,000 feet, leading the water into two reservoirs near the southeast corner of the city. About twenty years ago an inscription in archaic Hebrew was found on the tunnel-wall near the lower end. The following is a translation of this inscription from a French version in *Rev. d. Etudes Juives.* I am indebted to Prof. Morris Jastrow for the reference to this translation, and also for an emendation of it, reading "blind alley" (cul-de-sac) instead of "accident" of the French text. "End of the boring. Here is what relates to the boring. While the borers worked their picks in opposing directions, and there were 3 cubits to break through, they heard each other's voices, for a blind alley was disclosed in the rock on the right and left, and on the day of completion the borers faced each other face to face. The waters ran from the pool-spring 1,200 cubits. The height of the rock above the borers' heads was 1 cubit."

The tortuous course appears intentional, for shafts were driven at two different points. It has been suggested that this course was rendered necessary to avoid rock-hewn tombs. The spring was intermittent, and has even been supposed to have a symbolic periodicity. It is an interesting example of how a legend may arise and be propagated,

that a traveler who visited Jerusalem in A.D. 333, and who is known in history as the Bordeaux pilgrim, states that the pool of Siloam was inside the walls of the city and that the waters did not flow on the Sabbath.

Excavations along the southern wall of Jerusalem have

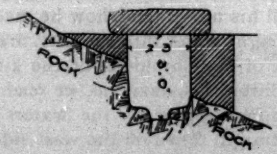


FIG. 2.—Cross-section of aqueduct.

brought to light an aqueduct passing along the northern slope of the Hinnom Valley, penetrating the wall and passing towards the southeast corner of the city. This aqueduct is well built, being hewn out of a rock with rather steep incline. The upper and lower sides were extended by

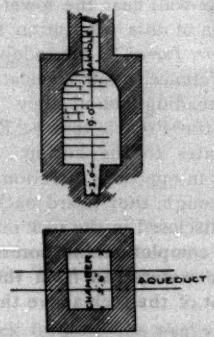


FIG. 3.—Cross-section of enlarged portion of aqueduct.

walls, so that flat cover-stones might be used. The cross-section of the channel is rectangular, with a depression in the center line of the floor. The dimensions are about 3 feet high and 2¼ feet wide. Rock-hewn manholes were provided. At one point there is a chamber 5½ feet long, 4 feet

wide, 9 feet high. F. J. Bliss, whose excellent work on the excavations at Jerusalem gives much information, thinks that this aqueduct is also the work of Solomon's time, but further information on this point is required.

In addition to these constructions, Bliss gives the lines of an aqueduct beginning to the west of Jerusalem, passing around by the south in the Hinnom Valley, and entering the city toward the east. This he terms the lower-water aqueduct, but gives no special information about it. We know from Josephus that Pontius Pilate "brought water into Jerusalem," but detailed information on this point is not available. His action provoked much dissatisfaction, possibly owing to exactions and oppressions practiced in carrying out the work. The name of this man has been anathema for so many centuries that we should not grudge him some honor for bringing in a new supply of water.

More extended excavations may be expected to yield still further interesting results as to the sanitary conditions of this ancient city.

ELECTROLYTIC REDUCTION OF LEAD.

On the subject of the electrolytic reduction of lead, Pedro G. Salom read a very interesting paper at the recent Philadelphia meeting of the American Electrochemical Society. He described the process invented by him and in use by the Electrical Lead Reduction Company at Niagara Falls. The ores that are reduced are sulphides of lead. They are used as cathodes in an acid electrolyte. The hydrogen ions combine with the sulphur of the ore and form hydrogen sulphide, which escapes as gas, while the lead sulphide is reduced to lead. This is the principle of the process. The apparatus used resembles in a general way a pile of dinner dishes of lead, piled one above the other. Each of these dishes represents a cell, the under side of a "dish" being the anode of the lower cell, the upper side the cathode of the upper cell. With forty-eight cells in series they use 130 volts and get 2 pounds of lead per horse-power hour.

The lead obtained in this process is in spongy form, and is then used for making other materials, like litharge. Owing to its spongy form, the lead is very readily transformed into litharge. Samples of spongy lead, compressed lead, litharge and other materials were shown. In future it is also intended to make accumulator plates.

The principal difficulty in the practical operation of the process was that the reduction was not complete, and that under apparently identical conditions the degree of reduction was not the same, especially as lumps of ore in the immediate neighborhood of the cathode plates were not reduced.

In the discussion which followed, the following explanation of this fact was offered: When the electrolysis begins, the parts of the ore near the electrolyte are reduced; when the electrolysis progresses the current may prefer to pass through the reduced lead to the cathode, hydrogen being developed and no lead sulphide being reduced. According to this view, the efficiency of the reduction would gradually diminish with progressing electrolysis. This would explain the fact that especially lumps of ore remote from the electrolyte are not reduced.

At present they have succeeded in improving the reduction so that about 92 to 95 per cent. of the lead sulphide is reduced to lead. Another difficulty experienced was that the workmen's eyes were affected during the operation by the escaping gases; but this difficulty appears to have been overcome.

As the developed gases are hydrogen sulphide and oxygen, in their combining proportions, it has been proposed to utilize them in gas engines, which then could develop more power than was used in the process. This apparent paradox was explained by Prof. J. W. Richards in the discussion.

The ores treated in the process contained no silver. No attempt is therefore made to refine the lead for producing silver.

MAGNITUDE OF COMMERCE ON THE LAKES.

The close of November on the Great Lakes usually marks the end of the season of through navigation; and the government statistics show that for the first eleven months of the past year, 77,408 vessels, of over 71,000,000 net tonnage, were reported as arrivals, and 77,899 clearances were reported, of over 72,000,000 net tons. There are twenty indvidual ports on the Great Lakes having a registered tonnage ranging from 1,000,000 to over 5,000,000 tons. Cleveland heads the list with 5,037,282 tons; and other ports, viz.: Duluth, West Superior, Milwaukee, Chicago and Buffalo, recorded over 4,000,000 tons of arrivals. The enormous volume of this movement is only appreciated when it is compared with similar marine operations on the ocean frontage. New York, during the entire year 1902, is credited with 8,982,767 tons of arrivals; London had entrances in 1901 amounting to 9,992,753 tons; and Hong Kong reported 8,626,614 tons entering in the year 1900.—*Scientific American.*

METALS IN THE HOUSEHOLD, ETC.

Professor Lehmann has reported on the significance of the hygienically important metals, aluminium, lead, copper, nickel, tin and zinc, in the household and in the food branches, at the meeting of the German Verein fuer oeffentliche Gesundheitspflege. Actually injurious and dangerous are lead and all lead preparations. Mercury poisoning in the household is too rare to deserve any mention. The poisonousness of copper, zinc and tin is very slight and greatly exaggerated by some authors. Silver, aluminium, iron and nickel may be called entirely harmless. Despite the slight hygenic value of all heavy metals, excepting lead and quicksilver, all endeavors to keep these metals away from our aliments, especially preserves, should be assisted.—*Neueste Erfindungen und Erfahrungen.*

CHEMICAL SECTION.

Stated Meeting, held Thursday, January 23, 1902.

Modern Methods of Rock and Mineral Analysis.

By Dr. W. F. Hillebrand,
U. S. Geological Survey, Washington, D. C.

Since those days in the life of our science, when the study of organic compounds being as yet hardly begun, much more of the time of the foremost chemical workers was devoted to the elucidation of the composition of minerals than was later and is now the case, the conditions governing chemical work have changed greatly. When rubber tubing was a thing unpurchasable and had to be made when wanted by the tedious process of pressing the edges of a strip of soft sheet-rubber together into an air-tight seam over a glass or other rod of the desired size; when the various reagents, too, had to be mostly made, and alcohol-lamps and charcoal-furnaces furnished the only means of procuring high temperature; when all the modern conveniences of an ordinarily well-equipped laboratory were lacking —filter-pumps, spectroscopes, electricity on tap at a moment's notice—at that time it was well perhaps that the chemical complexity of the earth's crust was so little suspected, else he had been a bold man who would tackle the composition of many of our common stones and useful minerals. Gallium, indium, thallium, germanium, with nearly all the growing host of rare earths, were to be discovered. It was long before titanium (about tenth in order of abundance) became recognized as more than a rarity among elements; and as to vanadium, now entering the lists of those eagerly sought by industrial interests, it was but one of many chemical curiosities whose commercial possibilities were undreamed of.

His was therefore a simple task in some respects compared with that of the analyst of to-day, yet, considering the means at his disposal, the results achieved are a stand-

ing monument to the skill and untiring perseverance of the great minds of those times. It is no discredit to them that their work in rock and mineral analysis is so little available to-day because of the higher requirements of modern classification both as to the quality and quantity of the ingredients.

It is in some respects surprising perhaps that the fundamental methods of chemical separation employed then remain in use so largely to-day, modified oftentimes in the direction of greater accuracy or simplicity as perception of the mechanism of the reactions involved has become clearer, but unchanged in principle.

Comparison of the methods of the present with those of the past is hampered by the difficulty, nay, impossibility, of deciding where yesterday ended and to-day began. There is no well-marked milepost dividing the one from the other, unless we choose to regard as such the introduction of heavy solutions for the purpose of obtaining in greater purity and quantity than was otherwise possible one or more of the constituents of a mineral mixture. While it is incontestable that the use of these solutions has done more to advance the study of minerals, particularly of those making up the complex rocks, than any one other thing, it has done so solely for the reason that we are thus often enabled to obtain our material in greater purity than heretofore and not because it has influenced in any way the chemical side of the problem.

Instead, therefore, of trying to establish an imaginary line it will perhaps be simpler to outline a small portion of the present practice and to show here and there wherein and why it differs from that of earlier times. My remarks will apply less to the technical than to the scientific application of methods. In general, the investigation of minerals and rocks requires far more searching work than the ordinary problems of technology, yet it is largely by the observations made along this purely scientific line that necessary improvements in the latter work are indicated and provided. This is but a minor repetition of the oft-repeated observation that the apparently unimportant discovery in

pure science of to-day may be worth fortunes to individuals and incalculable benefit to mankind in the future.

Instead of drawing my first examples from the simply constituted minerals and gradually leading up to those of a complex nature, I will plunge at once into that maze of complexity, a silicate-rock analysis. This I do to avoid the useless repetition that would result through working up from simple to complex compounds and finishing with the most complex of all, and for these other reasons: In the igneous rocks are probably to be found nearly all the elements existent in the outer regions at least of our globe, as is but natural, since the secondary geological formations and minerals must have had their origin in the former. The methods used for the separation of their numerous constituents are in large part those which would be employed in analyzing these latter separately; modified, however, oftentimes by the fact that many of these components are of very subordinate occurrence and hence require or admit of different treatment than if they were chief constituents.

A further reason for my choice of a working illustration is that the study of the composition of simple minerals is but an incident in the work of mineral chemists compared with that of the complex rocks whose classification is now demanding the best efforts of petrographers the world over. This problem calls for an ever-increasing number of analyses in order that the relations between the rapidly growing number of variations in rock species may be traced by affording the necessary chemical data without which no system of classification can be successfully evolved.

It is only in recent years that the need of exhaustive and elaborate analyses of rocks has come to be recognized by petrographers, and there are many who are still quite content with results which were generally deemed all-sufficient forty or thirty or even twenty years ago. Those workers who are trying to solve the great problem of rock-classification find themselves more and more hampered by their growing inability to make anything like adequate use of the great array of chemical data coming down to them from an earlier period, and even, be it said, of much of that of to-day.

This is not to be wondered at when it is recollected that such constituents as phosphorus and titanium, averaging together about 0·8 per cent. of the rock-crust of our globe, were seldom looked for; that the utterly untrustworthy "loss-on-ignition" method was usually deemed sufficient for water, and that such constituents as barium, strontium and vanadium were practically undreamed of as rock-constituents. I have pointed out on other occasions the erroneous conclusions that must of necessity follow from such defective work, yet I do not think that any apology is needed if I again draw attention to an example.

	a.		*b.*	
	Earlier Analysis.	Later Analysis.	Earlier Analysis.	Later Analysis.
SiO_2	54·42	53·70	44·31	44·65
TiO_2		1·92		·95
ZrO_2		·20		
Al_2O_3	13·37	10·96	17·20	13·87
Cr_2O_3		·04		
Fe_2O_3	·61	3·10	4·64	6·06
FeO	3·52	1·21	3·73	2·94
MnO		·04	·10	·17
CaO	4·38	3·46	10·40	9·57
SrO		·19		·37
BaO		·62		·76
MgO	6·37	6·44	6·57	5·15
K_2O	10·73	11·16	3·64	4·49
Na_2O	1·60	1·67	4·45	5·67
Li_2O	trace.	trace.		trace.
H_2O 110° —		·80	·77	·95
H_2O 110° +	2·76	2·61		2·10
H_2O ignition			3·50	
CO_2	1·82			·11
P_2O_5		1·75		1·50
SO_3		·06		·61
F		·44		
Cl		·03		trace.
	99·58	100·40	99·11	99·92

These analyses were made by different chemists, and in the first case at widely separated times and on specimens collected by different geologists, but nevertheless, from the same rock-mass, in which, however, much the relative proportions of the different mineral constituents might vary within certain limits, there can be no reason to doubt the

general distribution of all the elements shown by the later analysis.

What wonder is it that no satisfactory conclusions result from an attempt to calculate the mineral composition of these rocks from the early analyses, wherein from 3 to 4 per cent. of acidic oxides have been overlooked, with the further result that the bases have been found too high to the extent of the neglected titanium and phosphorous oxides which were mostly weighed with the alumina? If, by chance, calculation had led to seemingly satisfactory balancing of acidic and basic oxides, the result would be decidedly more unfortunate than if this had not been the case, for it would have tended to establish the rock in an altogether erroneous position, whereas, otherwise, at the worst its position would be so in doubt as to lead perhaps eventually to a re-analysis.

The custom of neglecting to make preliminary qualitative tests in rock analysis is the prime cause of many gross errors like the above, but this neglect is doubtless attributable to lack of time for their execution, since some are not altogether simple or to be disposed of in a few moments.

In analyzing minerals as distinguished from rocks, errors of the kind above noted are less frequent. There it is and always has been the almost invariable custom to make a careful qualitative analysis first, and not to assume the presence of only a few unvarying constituents in measurable amounts.

The difficulty in the way of attaining correct and easily interpretable results was mainly due to lack of means for ascertaining whether or not the material was pure (especially with uncrystallized material), and still more perhaps to inability to identify or to separate the certain or suspected impurity or admixture. Of course, if its composition were known, this might now and then be allowed for in calculating a formula, but if unknown, any result must be more or less affected with doubt. The polarizing microscope has done much to overcome the first of these difficulties, and in the case of rocks to afford invaluable hints to the chemist as to what unusual constituents he should be on the lookout for or for what commoner constituent in quantities out

of the ordinary. And by the use of the so-called heavy solutions mysteries have been solved which hitherto had resisted the ablest efforts of master-hands and minds; for by their aid has it been possible often and often to obtain material of a degree of purity quite unattainable by panning or laborious hand-picking, or partial attack by acids, or any combination of these processes.

These two devices, the polarizing microscope and heavy solutions, have done quite as much, if not more, to help the mineral chemist than the perfecting of methods or better understanding of the chemical behavior of compounds he has to deal with.

Until the application of these solutions become known the petrographer must needs calculate the relative proportions of his rock minerals from the bulk analysis and assumed compositions for the constituent minerals, and thereby run often into error, for he could by no means always be sure that his minerals had in fact the composition assumed for them. Now, however, he can, when necessary, separate them from one another, analyze one or several of them, and discuss the results of the bulk analysis with confidence instead of doubt.

While the use of heavy solutions does not pertain to the domain of chemistry, they play such an important part in the preparation of material, and are so often employed by the chemist himself, that brief descriptions of the agents themselves and their manner of utilization may be regarded as a fitting prelude to the chemical side of this paper.

HEAVY SOLUTIONS AND SEPARATORY APPARATUS.

Although the idea of separating mixed solids by taking advantage of their difference in density was long ago suggested and to a slight extent applied, as by using an upward current of water or a solution of mercuric nitrate, the first of the so-called heavy solutions to come into general employment was a double iodide of mercury and potassium, first proposed by Sonnstadt in 1873. It therefore properly bears his name, though it is more commonly called by that of Thoulet, who first devised an apparatus for its convenient

use. After Goldschmidt had studied the subject exhaustively and showed the great value in several ways of the solution, as well as defined its limitations, petrographers first became fully awake to the fact that a powerful handmaiden had arisen to further the strong advance inaugurated by the polarizing microscope.

This solution is made by dissolving potassium iodide and mercuric iodide in proportion of 1:1.239 in a minimum quantity of water. The maximum density attainable by evaporation of this solution is generally stated to be 3.196, but I have had no trouble in reaching repeatedly 3.25 and over. By dilution with water this can be reduced as desired. The majority of rock-forming minerals can be separated by this solution, and it is the simplest to make and the easiest to use perhaps of all similar solutions, though somewhat corrosive in its action on the skin and suffering from one drawback incident in its relatively low density compared with other heavy solutions in use, namely, that many minerals have a density superior to its maximum. For the separation of these from one another, solutions of greater density had to be sought, and were before long forthcoming.

The Frenchman, Klein, introduced cadmium-boro-tungstate, either in concentrated solution with a maximum density of 3·36 or in fusion at 75° C., when its density reaches 3·58. But its preparation is extraordinarily difficult and uncertain, and it undergoes somewhat ready decomposition with separation of a white deposit which cannot again be brought into solution.

Rorbachs' solution of barium-mercuric iodide, attaining a maximum solution density of 3·588, is useful at times for minerals heavier than the Sonnstadt solution. Its proneness to decompose when diluted with water renders it less serviceable for lighter bodies.

Methylene iodide of density 3·3155 at 20° C., because of its mobility, has been well spoken of in recent years, but I have had no opportunity as yet to test it. Dilution in this case has to be effected by benzol or toluol.

Mixtures in varying proportions of thallium and silver nitrates are useful on occasion for separating minerals

heavier than any of the agents already spoken of. These are used in fused condition, the equi-molecular mixture having a fusion density of 4·5 at 75° C. By increasing the proportion of thallium, heavier compounds fusing at higher temperatures are obtained, till with 1 $AgNO_3$ to 4 $TlNO_3$ the density is 4·94 and fusing temperature 250° C. It is disagreeable to handle because of staining the skin, and as a good substitute, mercurous-thallium nitrate has been proposed.

Then there is the fused mixture of lead and zinc chlorides with density 4–5.

In using these various agents certain precautions have to be observed; for instance, the Sonnstadt solution is attacked by some metallic substances, as iron, zinc, nickel, also perhaps slowly by sulphides and certain oxides; hence, it becomes in time seriously contaminated and darkens in color. This last defect is soon corrected, however, by digestion of the liquid with metallic mercury. The maximum density suffers somewhat in consequence, after a time, but with ordinary care the same solution may be used for many years with little impairment of density.

The cadmium-boro-tungstate solution likewise attacks metals and also carbonates, while the silver-thallium nitrate attacks most, if not all, sulphides.

In making separations by these solutions it is useless to expect quantitative results with natural mixtures. There is always too much intergrowth or inclusion of different minerals, no matter how fine the subdivision may be. This comminution cannot be carried beyond a certain limit either, because of the extreme slowness of separation of very fine particles, just as with clay suspended in water; consequently, there is almost always a waste, and often a very great waste of substance. The first separated portions must usually be again treated with fresh solution in order to remove foreign grains carried down or up with the material which it is desired to obtain pure. Careful examination with the polarizing microscope must decide as to the condition of the ultimate product.

With some solutions, especially the Sonnstadt, these

separations can be made in ordinary breakers or crystallizing dishes, or straight-sided separatory funnels, particularly the first crude separations. But usually special apparatus are employed which allow more ready removal of the heavy portions of mineral than is possible with those vessels which, like beakers, have no outlet at the bottom. Some of these I will now show and explain the manner of operation. [At this point various forms of separatory apparatus were exhibited and described.]

SPECIFIC GRAVITY BY HEAVY SOLUTIONS.

Having now obtained our material in a condition fit for analysis, I will not take up time in telling how its specific gravity may be determined, except in so far as this is done indirectly by means of some of those same heavy solutions of which I have just spoken. The specific gravity of a solution in which a fragment of rock or mineral remains suspended at any depth, without rising or sinking, is necessarily the specific gravity of that fragment. Hence, in making separations by the aid of solutions which are liquid at room-temperatures, it is often convenient to determine the density of the liquid wherein a particular mineral neither sinks nor swims in order to know that of the latter. This is most conveniently done in a few moments by the Westphal balance. Since in crushed condition not all grains or fragments of a mineral possess exactly the same density, we have here a handy means of ascertaining the extreme limits of density of all the grains. It is only necessary to determine the density of the liquid in which a few grains begin to fall and again after diluting it till all have fallen. Especially convenient for density determinations are the heavy solutions when but a few small fragments are available, insufficient for determination by the usual methods.

DISCUSSION OF CHEMICAL METHODS.

I will now begin the chemical discussion by briefly considering a method for the breaking up of silicates more or less insoluble in hydrochloric acid—a method discovered prior to 1805 by Sir Humphrey Davy and rather recently reju-

venated by the German chemist, P. Jannasch, who expects it to entirely supersede the sodium-carbonate method of fusion for most fine work. This latter method, as you are aware, introduces a large amount of fixed alkali salt into the analysis, whereby the thorough washing of precipitates is rendered difficult.

Jannasch decomposes the silicate by fusion with pure fused boric oxide, using the oxy-gas flame for certain silicates like andalusite, cyanite and topaz, which are not fully decomposed over the ordinary blast.

After transferring the contents of the crucible to a large dish the boric oxide is driven off as boric ether, by digesting and subsequently evaporating several times with a saturated solution of hydrochloric acid in methyl alcohol.

Very much is claimed for this method by its authors and it is manifestly superior to the alkali carbonate method when material is scanty, for it admits of determining the alkalies in the same portion as the silica, lime, manganese, etc. As yet I have been unable to submit the method to critical test and am unable to express an opinion as to its real merits, though I hope to be able to do so before another year passes. One or two objections occur to me which probably are well founded, in part at least, but there is no question apparently that at times the method may render inestimable service. It will, however, probably not displace the sodium-carbonate method in technical work, even should it do so to a large extent where the extreme of accuracy is desired.

For the determination of certain constituents in silicates the method offers little or no advantage, or is even not at all adapted, as for instance, phosphorous, arsenic, vanadium, sulphur, chlorine, fluorine.

In connection with this last element an interesting observation was made by Jannasch and Weber, which it is my intention to look further into. They found that over the oxy-gas blast fluorine, if present, was wholly driven off as fluoride of boron without involving any loss of silica as silicon fluoride. An easy means seems to be thus afforded for determining silica in fluorine minerals where even its detec-

tion in small quantity has heretofore been difficult in the last degree, if not impossible.

I will now take up the question of the ordinary determination of this compound silica which constitutes the major part of the solid crust of our globe. The ordinary method for its determination is, of course, familiar to you all, yet how far short of perfection it is, especially when, as is usually the case, the chemist is wholly or partially ignorant of its defects, the following list of determinations shows:

	Raw Cement Mixture.		Finished Cement.	
	SiO_2	Per Cent.	SiO_2	Per Cent.
Standard.	15·18	100·	21·31	100·
1	15·75	103·7	20·90	98·1
1a	15·37	101·2	—	—
2	14·68	96·7	20·92	98·2
3	13·92	91·7	20·06	94·1
4	—	—	20·00	93·9
5	14·18	93·4	20·26	95·1
6	14·70	96·8	20·96	98·4
7	12·78	83·7	20·84	97·8
8	13·97	92·0	19·82	90·5
9	14·44	95·4	20·76	97·4
10	13·60	89·6	19·18	90·0
11	14·64	96·4	21·46	100·3
12	14·18	93·4	20·76	97·4
13	14·92	98·3	21·56	101·2
14	13·56	89·3	19·53	91·2

The results of this table formed the basis for a paper, an abstract of which I delivered in this city less than a month ago, and a part of what I am now about to say will therefore bear a familiar sound to those of you who were present at that time.

The figures represent silica determinations in the same samples of raw-cement mixture and of finished cement from this mixture, made by fifteen different chemists at the request of a committee of the New York Section of the Society of Chemical Industry for promoting uniformity in technical analysis. My own connection with the work was that I was requested to analyze the samples with the care usually bestowed on rock and mineral analysis in the Geological Survey Laboratory, in order to learn exactly the

composition of these samples and thus to have a standard for comparison. The first determinations of the list represent the standards, which are probably in error by 0·1 per cent. to 0·2 per cent. at most, that of the finished cement being possibly as much as 0·2 per cent. too low. Later, after all the data, including methods used, had been collected, copies of these were turned over to me for critical examination as to the causes for the grave discrepancies in most of the analyses and for suggestions looking toward the removal of these causes. It should be understood that the most of these analyses were made for technical purposes, and that only the care usual in such cases was expended on them.

I can very well recall, when making my first silicate analysis under the revered Bunsen, that we evaporated the hydrochloric solution of a rock, after fusing with sodium carbonate, for six to twelve or more hours on the water bath to insure perfect insolubility of the silica. Then, at a subsequent stage in the analysis we dissolved our ignited precipitate of iron and alumina in hydrochloric acid and filtered from a small residue of silica. What to do with this, whether to regard it as belonging to the rock or as derived from the porcelain dish used for evaporating or from the beaker in which precipitation was made, or from these and reagents as well, was never made clear to me, but my impression is that we rejected it.

Now, while a portion of this silica may have had and doubtless did have its origin in other sources than the rock, experience of many years has taught that it is mainly to be ascribed to incomplete separation by evaporation of all that was in the rock, and hence arose the custom in all really careful work to recover from the iron and alumina that which had escaped and accompanied these other bodies when they in turn were precipitated. As recent experiments of mine have shown, this last procedure involves two errors which had hitherto been hardly more than suspected, and the detection of which emphasized all the more strongly the recommendation of Cameron made a number of years ago to remove all silica at the start by several alternating

evaporations and filtrations. It has been my own practice ever since that time to evaporate once to moderate dryness, then filter, then evaporate again to thorough dryness, and thus recover all but a very slight amount of the total silica. Cameron showed, and I have been able fully to confirm his statements, that it is impossible to render silica insoluble by evaporation to dryness, no matter how prolonged the drying may be or at what temperature it may be carried out, if only one filtration is made. Cameron, in his third and fourth filtrates, still found appreciable quantities of silica. My own results were more favorable, as from the second filtrate I never recovered more than a milligram of silica, and often much less. I ascribe this latter success to the fact that I used platinum instead of porcelain dishes.

The bearing of these remarks upon the figures of the table becomes plain when it is learned that in no case but the standard and No. 1 does it appear that a second evaporation and filtration were carried out, although it is evident from their descriptions that all the chemists strove honestly, according to conventional methods of dehydrating silica, to secure its complete separation.

There has long been found a statement in text-books that silica thus separated from solution needs to be strongly blasted to bring it to correct and unchangeable weight. The statement is unqualifiedly true in spite of a contrary one in Treadwell's recent text-book on quantitative analysis, which is based on experiments of Lunge and Millberg with silica derived from silicon-tetrafluoride. The condition of silica thus obtained seems to differ from that of silica precipitated from a silicate by hydrochloric acid in the ordinary course of analysis. The errors resulting from a failure to apply the blast to this latter form of silica are shown by Table III, which represents experiments on quartz 99·88 per cent. pure. In these cases the blast was applied for half an hour, after one hour's exposure to the heat of a good Bunsen flame, and yet the results are a little high in most cases and could have been lowered still more by doubling the time of blasting.

TABLE III.

	Silica found.				Percentage found.	
	Quartz.	Burner 1 hour.	Blast ½ hour.	Loss in weight.	Burner.	Blast.
1	·5738	·5761	·5735	·0026	100·40	99·95
2	·5931	·5945	·5930	·0015	100·24	99 98
3	·6401	·6450	·6394	·0056	100·76	99·90
4	·6638	·6668	·6628	·0040	100.45	99·85
5	·7028	·7058			100·25	
6	·7309	·7342	·7306	·0036	100·45	99·96
7	·8208	·8271	·8206	·0065	100·77	99·98
8	·8495	·8521	·8484	·0037	100 31	99·88
9	·8943	·8995	·8936	·0060	100·59	99·92
10		·9989	·9898	·0091		

Now, as it happens, but few of the silicas of Table II were blasted; moreover, not all or many of them were corrected by hydrofluoric acid for the invariably contaminating impurities, which in case of very basic rocks rich in iron, titanium and phosphorus may reach the sum of 1½ centigrams, or even more in extreme cases, where a gram of rock sample is under treatment. Hence, the results as given are in most cases still too high, and the excesses of a few over the standard are thus seen to be probably apparent rather than real.

The analyses under discussion did not end with determination of silica. Other constituents were determined, and it was noted that the sum of iron, titanium, aluminum, and phosphorous oxides was in almost every case markedly in excess of that of the standard analysis. From what has been said, the cause of this excess is plainly the precipitation and weighing of most of the missing silica with the oxides mentioned. Most, but not all; for while a large excess of ferric or aluminum hydroxide carries down with it a large part of the silica in solution, a portion of this last escapes precipitation and passes on into the filtrate. With a double precipitation the loss is of course increased. This is one of the errors I mentioned a few moments ago and which I have recently found in a number of tests to range between ·0007 gram and ·0023 gram for a single precipitation. The silica thus lost probably passes mainly into the final filtrate from the magnesian phosphate and escapes

estimation entirely. The second of the errors I will now consider.

Many chemists practise the custom of fusing the ignited alumina and ferric oxide with potassium pyrosulphate, in order to recover the silica contained in them, and probably considered the recovery nearly perfect; at least, I do not recall any expression of doubt on this point. That it is, however, very far from perfect was shown in the paper read in this city a few weeks ago and to which I have already referred. On dissolving the fused mass in water or dilute acid a considerable proportion—several milligrams—of silica may go into solution. It is true that, by adding to the solution-excess of sulphuric acid and evaporating till fumes come off strongly, the dissolved silica can be rendered insoluble and recovered; but this course was never pursued, because its need was unrecognized.

We thus have an additional and strong argument in favor of removing all silica at the start by two, or maybe even three evaporations, with as many filtrations.

I have dwelt thus at length upon the determination of silica not only because it is of such common occurrence and constitutes so often a large percentage of the substance analyzed, but also because uncorrected errors, like those described, do not end there but affect later estimations of other substances in the same portion of sample.

Passing now to the determination of the several components of the rock that may be collected together by means of ammonia or the basic acetate process, we find that the more modern changes in the manner of effecting their joint precipitation have aimed at greater perfection of separation without introducing any radical modifications in the methods themselves. It is now fully recognized that two precipitations by ammonia are necessary to free from calcium unless carbon dioxide is carefully excluded from contact with the ammoniacal liquid, and that unless large amounts of ammoniacal salts are present many times two will not suffice to keep magnesia out of the precipitate. Ignorance or neglect of this precaution has been the cause of countless faulty analyses. With very large magnesia

content, and much iron or aluminum, three precipitations may be necessary, even with a sufficiency of ammoniacal salts.

It is still the custom with most chemists to boil until all excess of ammonia is expelled, not only to effect resolution of precipitated magnesia but also to complete, as supposed, the removal of the last traces of alumina from solution, notwithstanding that both Genth and Penfield long since showed that the presence of alumina in the filtrate was due to prolonged washing with water much more than, if at all, to the solvent effect of ammonia in excess, and that Penfield, by the use of wash-water containing about 4 per cent. of ammonium nitrate, obtained filtrates almost entirely free from alumina.

The basic-acetate method has been the subject of innumerable researches having in view the molding of it into such shape that it might be depended on to give satisfaction in all hands, but undeniably without complete success. It has been shown that an undue excess of acetate should be avoided, and turbid filtrates can generally be prevented by adding a little of the precipitant to the wash-water. The testimony of different writers as to the efficacy of this agent as a means of separating iron from nickel, cobalt, and manganese is still conflicting, some maintaining its adequacy, others preferring to precipitate several times by ammonia in presence of much ammoniacal salt.

The collection by one or the other of the means outlined of all precipitable bodies that may be in the original solution being thus accomplished, the question now arises how to separately determine them after their combined weights have been ascertained. There is a well-founded prejudice against estimating a constituent of a mixture by difference if it can be equally well determined directly, but there are those who allow their prejudice to carry them too far. If the mixture is simple, the separate determination of each component may be exact and more or less easy, but if complex, this is not often so. For instance, there is no particular difficulty in dividing satisfactorily a mixture of iron and aluminum oxides into its component parts and weighing

each separately. If titanium forms a third component the task is more arduous though still possible, but with the addition of phosphorous, either with or without the titanium, the uncertainty is increased to such an extent as to render the choice of an indirect method for one of the components almost imperative. When vanadium, chromium, perhaps zirconium and rare earths, one or all, are included in our mixture, the task is a hopeless one, for each requires its special reagent for gravimetric, volumetric, or colorimetric estimation, whereby impurities or other disturbing factors are introduced to cloud each successive step.

In any mixture of the above-mentioned compounds there are reliable and direct means of estimating all except one, provided that they need not all be sought in the same aliquot part. This one is alumina. By no method or combination of methods with which I am familiar can, from such a mixture containing phosphorous, the alumina be isolated except by the introduction of probable errors far outweighing those incidental to its indirect determination. Therefore I regard it as far more accurate ordinarily to obtain the gross weight of all components of the mixture, then to determine all of its components but the alumina, partly in separate portions of the sample, partly in our weighed mixture, to deduct their sum from the known weight of all, and thus to arrive at the weight of the final unknown quantity. This course necessarily presupposes that the utmost pains were taken to obtain the mixture free from all contamination and of fixed and invariable condition of oxidation.

The objections which others have held or still hold are mainly founded on ignorance or disregard of the oftentimes complex nature of this precipitate produced by ammonia or sodium acetate. So long as the lesser constituents were not known, or were supposed to occur in only negligible traces, these objections had a basis for argument which with fuller knowledge no longer obtains.

Taking up now the methods of separating and estimating the constituents of this mixture I have so often alluded to, we find that important changes have been introduced in the

best practice, both as to the means of separation and ultimate determination. Titanium, which was such a bugbear in former years, is now one of the elements whose quantitative estimation offers few difficulties by colorimetry, if not in excess of a few per cent., otherwise by the excellent Gooch method, if zirconium is not at the same time present.

The old-time method of long boiling of the nearly neutralized and very dilute sulphate solution in presence of excess of sulphur dioxide to reduce and prevent co-precipitation of ferric iron, with its uncertainties and inconveniencies is, in this country at least, practically abandoned. The method so carefully worked out by Gooch depends upon the precipitation of titanium by boiling its sulphate solution, whose excess of acid has been neutralized by sodium acetate and to which then a certain measured excess of acetic acid has been added for the purpose of holding up alumina. Iron is supposed to have been first removed by ammonium sulphide in tartaric solution, the excess of tartrate being then destroyed by permanganate before precipitation of the titanium.

Zirconium, a frequent constituent of rocks, has been found to interfere with this gravimetric estimation by holding up much or all of the titanium. Hence, for rock-work, where titanium is not in great amount, the colorimetric method offers opportunity for its easy and exact determination. This, devised by Weller, and studied further by Dunnington and myself, consists in the oxidation of a sulphate solution of titanium by hydrogen peroxide, whereby the solution becomes colored a powerful yellow to reddish orange admitting of ready comparison with a standard solution similarly peroxidized. Necessary precautions are the employment of a solution sufficiently acid to prevent reversion to unoxidizable metatitanic acid and of peroxide of hydrogen free from all traces of fluorine compounds, which we often find in commercial samples. These prevent the appearance of the full color of the titanium peroxide and thus lead to false results.

[*To be concluded.*]

Committee on Science and the Arts.

The Taylor-White Process of Treating Tool-Steel.

[*Being the Report of the Committee on the Invention of Maunsel White and Fred W. Taylor. Sub-Committee: Charles Day, James Christie, Coleman Sellers, Arthur Falkenau, Wilfred Lewis.*]

Your Sub-Committee submits the following report on the Taylor-White process of treating tool-steel.

About three years ago an extensive series of experiments were undertaken at the Bethlehem Steel Works, by Messrs. Taylor & White, in order to determine the relative efficiency of various brands of tool-steel on the market at that time.

There are two distinct classes of tool-steel, namely, carbon and air or self-hardening. The later brand, the result of Mushet's work, has completely replaced the carbon steel for roughing, its comparative efficiency approximately being 1·5 to 1·0. Mushet discovered that by the addition of manganese and tungsten to tool-steel it maintained its cutting edge at much higher temperatures and consequently much higher speeds were possible. The general introduction of this steel did not, however, take place as rapidly as one would suppose, the manufacturers failing to appreciate the great economy realized by using it. In fact, very few of the shops that did use it obtained the greatest efficiency possible, as no knowledge of cutting speeds and feeds was at hand.

The object of the experiments above referred to was largely to obtain this data for different materials and to determine the tool best adapted to their work.

It was found that the results obtained from different tools made from the same steel varied greatly, and as the only way of accounting for it was by variations in the process of hardening, it was decided to make a thorough investigation along these lines.

Having decided upon a brand of steel, tools were forged and heated to different temperatures and then put in a lathe

and tested. It was found that those cooled from a very high temperature gave remarkable results far surpassing anything yet accomplished.

It must be understood at this point, that all air-hardening steel, manufactured up to this time, was hardened by heating to a cherry-red and either allowed to cool gradually or in a blast of air. Users were invariably cautioned against overheating, cherry-red being specified as the desired temperature.

The above tests marked the beginning of a most thorough series of experiments, the object being to determine the best chemical composition and temperature for treating. In carrying out the above experiments a 66-inch Bement-Miles lathe was belted to an Evans friction-cone countershaft, it in turn being geared to a 40 horse-power Westinghouse motor. By this means any desired speed could be obtained. A depth of cut of $\frac{3}{16}$ inch and feed of $\frac{1}{16}$ inch with a duration of test of twenty minutes was adopted as standard. Two hundred tons of forgings were cut up in carrying out this work, the total cost aggregating $100,000.

A review of the patent specifications may now be well in order that we understand exactly the claims made. Messrs. Taylor & White say in part: "Our invention relates to the manufacture of tools for cutting metals or similar uses where the tool is highly heated in performing its work, the object of our invention being to provide a tool capable of working at higher temperature, and consequently doing more work in a given time than the tools as heretofore made." The above statements make it very clear that the tool is adapted to *roughing work only*, and unless sufficient speed can be obtained, no gain in output can be had. We wish to make this point perfectly clear.

Again, on the first page of the patent papers (Pars. 65–90), we find a general statement of the invention which may be worth quoting: "Our invention is based on our discovery that, while it is true tools made of air-hardening steels all deteriorate at temperatures in excess of a bright cherry-red (though it must be understood, not all at the same temperature), it is also true that when air-hardening steels are

made with certain constituents in ascertained proportions this deterioration only prevails during a limited range of temperatures above the bright cherry-red; that is to say, from about 1,550° F. to about 1,700° F. (corresponding to a light-salmon color), and on our further discovery that above this range of temperature, which we will call the "breaking-down point," and from 1,725° F. up to a temperature at which the steel softens or crumbles when touched with a rod

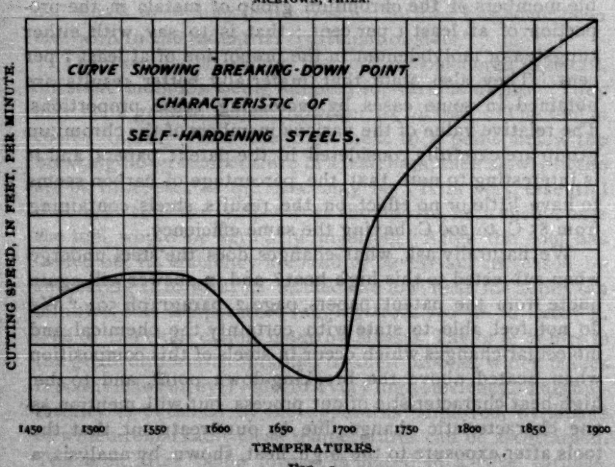


FIG. 1.

(approximately 1,900° or 2,000° F.) the efficiency of tools of such special steels; that is to say, their cutting speeds, and also their uniformity in efficiency, is greatly increased and largely so in proportion to the degree of heat to which they are raised. This is so much the case that their cutting speed may be stated to be from one and a half to two and a half times that of the tool heated as heretofore, to a temperature below the breaking-down point. The accompanying curve of temperature and cutting speed shows very

clearly in a graphical manner the principle of the Taylor-White discovery, and also the reason why a cherry-red was deemed best heretofore, as the curve falls off at this point.

How true the above statement of increased efficiency is, can be judged later when considering the experiments made recently by the Sub-Committee.

In order to obtain a suitable steel for the Taylor-White treatment it is necessary that it should be compounded with chromium in the proportion of at least one-half of 1 per cent., and another or other members of the commercially available members of the chromium group of metals in the proportion of at least 1 per cent.; that is to say, with either tungsten or molybdenum in the proportion of at least 1 per cent. They also state that materially better results are obtained in some cases by increasing these proportions. The relative value of the various members of the chromium group are carefully considered in the patent papers, and it is interesting to note that the percentage of carbon seems to have little or no effect on the results, steels containing from 85 C. to 200 C. having the same efficiency.

We naturally ask, what changes does the steel undergo when subjected to this high heat? and in answer will again quote from the patent papers, page 2, paragraph 50: "We do not feel able to state with certainty the chemical and molecular changes which occur in steels of this composition when heated above the breaking-down point, and to the high-heat characteristic of our process, but will mention as one characteristic change due to our treatment, that the tools after exposure to the high heat, shown by analysis, a *smaller* percentage of carbide of chromium than existed in the steels before such treatment, for example, in steels containing $1\frac{1}{4}$ per cent. chromium and $\frac{1}{10}$ per cent carbide of chromium, the tool after treatment contained but $\frac{3}{10}$ per cent. of carbide of chromium, and in steels containing $\frac{3}{4}$ per cent. of chromium and $\frac{8}{10}$ of carbide of chromium, the treated steel contained but $\frac{3}{10}$ per cent. of carbide of chromium.

Again, air-hardening steels of this composition, like air-hardening steels in general, possess in their normal condi-

tion the characteristically fine velvety grain when fractured. The higher range of temperature necessary in our treatment has a very noticeable tendency to change the structure of the metal and to give a non-velvety appearance and coarser grain, frequently interspersed with sparkling grains. "When treated with the higher heats and to obtain the best results, the steel of the tools shows under the microscope a distinctly large-grained structure, in many cases intercepted with austenite or microconstituent of steel discovered by Osmond, the chemical composition of which is unknown, and which, according to the best authorities, has never been met with in the industrial treatment of steel."

The question of cooling the tool is considered in detail, different methods being adopted for various duties. They may be in general stated, however, as follows: The tool is cooled rapidly from the high heat to a point below the breaking-down temperature in a lead bath, then slowly in the air or lime, etc., as the case may be. It is very essential that at no time the temperature should rise, as in such a case the tool would be seriously impaired. After the tool has cooled off, its efficiency is found to be further increased by subjecting it to what is termed the low heat for about ten minutes, this temperature ranging from 700° F. to 1,200° F. One of the chief claims made by Messrs. Taylor & White is the great uniformity obtained by their process, which makes it possible to run every tool to a very high efficiency. This uniformity is obtained by the apparatus employed, by means of which remarkably close temperatures can be ascertained. The tool, after being forged, is placed in a coke furnace, where it is heated gradually to a high heat, the latter being designated as the point at which the steel crumbles when tapped with a rod. As the tool is incandescent at this point, it is necessary that the operator wear colored glasses while testing for heat.

After heating, the tool is rapidly drawn from the furnace and plunged into a lead bath, which is maintained at a certain temperature by a very ingenuous method; a sketch may help to make this part of the process more clear. The cast-iron retort shown is heated from below by means of a coke

fire, the intensity of which may be increased at will by means of a blast of air. If the temperature rises too high, the closed pipe *P*, which has cold water circulating in it, can be lowered into the bath. The temperatures are determined as follows: From a lip in one side of the crucible is placed a pipe *T*, which projects into the lead bath. This pipe is enclosed in

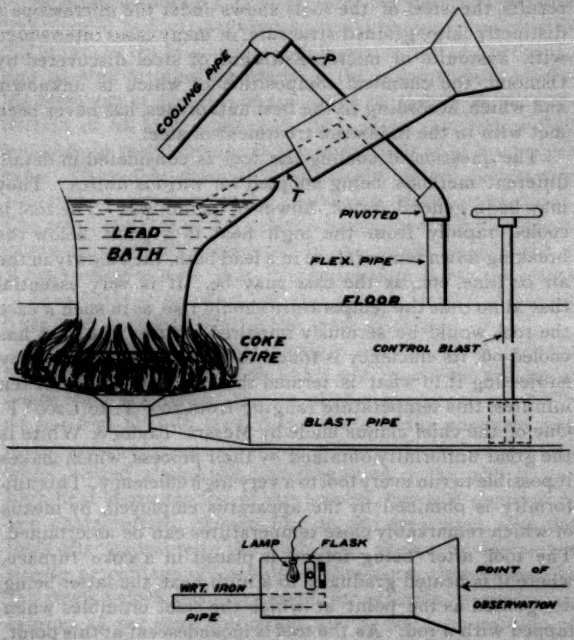


FIG. 8.

turn in a wooden tube blackened inside, also containing a flask of fluid lighted by an incandescent lamp in such a position that its color may be compared directly with the bath as seen through pipe *T*. Great care has been exercised in obtaining chemical ingredients for different temperatures that would be uniform, and of course the lamps must be

standarized and voltage kept constant by means of a rheostat. It must be thoroughly understood that it is in no way essential to use apparatus of this character to obtain a treated tool. In fact, your Committee has seen very good results obtained from tools treated in an ordinary smithshop fire and cooled in a blast of air. We do not feel, however, that the uniformity can be had by the latter method, and as it is this point that makes the treatment so valuable, we think that the great stress should be laid on the apparatus. The tools at Bethlehem are treated by laborers, who receive $1.35 per day. It might be well to mention at this point that in some cases where it is desirable to grind the tool before treating, a flux is used in order to prevent burning at the high heat.

In order to verify the statements made in the patent papers with regard to increased efficiency at high speeds, and to investigate the apparatus above referred to, your Committee visited the Bethlehem Steel Works on December 20 and 21 in 1901. Various brands of air-hardening steel were purchased and hardened in the presence of the Committee, according to the manufacturers' instructions. These tools were forwarded to the Bethlehem and ground to the standard angles as given below. The tests were primarily made out at Bethlehem on account of the experimental lathe above referred to, it being the only one where any desired speed could be obtained with sufficient power to pull the cut. Three different test-pieces were experimented on—two of steel and one of cast-iron. All the tools that were tested were brands that were on the market at the time the Taylor-White patents were granted.

Numerous tests have been made before and published, but none that we had access to showed the relative value of various tools in the true light; consequently we decided to run the tools at the same depth of cut and feed, varying the speed in order that each tool should last twenty minutes. It will be seen at once that an exhaustive test of this kind would take a very long time, as the speed must first be approximated many times before the right one can be obtained. The consequence was that the tests were not as

full as we had desired, but we feel they are sufficiently convincing for our purpose.

Tool-Steel Tested.	Date.	Exp. No.	Forging No.	Feed.	Depth of Cut.	Cutting Speed Aimed at.	Duration of Cut.	Average Cutting Speed Obtained.	Condition of Tool at End of Run.	Remarks.
				inch.	inch.					inch.
T.W.H. 2313	Dec. 19	1	7238C‡	1/8	1/8	11	20	11	Fair	5⅞ travel
Mushet	"	2	"	1/8	1/8	5	(*13½)	5	Point gone	1⅛ "
"	"	3	"	1/8	1/8	3½	(†13½)	3½	completely gone	1⅝ "
Sanderson .	"	4	"	1/8	1/16	3½	20	3½	"	1⅞ "
Boreas	"	5	"	1/8	1/16	4½	20	4½	"	2 "
Mushet	"	15	"	1/8	1/8	3	4	3	"	
Baeburn . .	"	17	"	1/8	1/8	3	20	3	fair	1¾ "
Mushet . . .	"	18	"	1/8	1/16	3	20	3	gone	1¾ "
T.W.M.E. 2836	Dec. 20	6	19788B‡	1/8	1/8	140	20	140	good	39¾ "
Sanderson . .	"	8	"	1/8	1/8	72	20	72	fair	19¾ "
Mushet . .	"	9	"	1/8	1/8	72	1¾	72	gone	1¾ "
Boreas	"	10	"	1/8	1/8	72	6½	72	"	6½ "
Mushet	"	11	"	1/8	1/8	60	19	60	"	15¾ "
Sanderson .	"	17	"	1/8	1/8	82	19¼	82	"	22½ "
Benj. Atha . .	"	13	"	1/8	1/8	82	13	82	"	15¾ "
T.W.M.E. 2757	"	14	"	1/8	1/8	156	20	156	good	40⅜‡ "
T.W.B. 0·3 . .	"	19	1506A	1/8	1/8	70	20	70	gone	16 7/16 "
Boreas . . .	"	20	"	1/8	1/16	55	20	55	good	12¾ "
"	"	21	"	1/8	1/16	60	3·8	—	gone	2 1/16 "
Mushet . . .	"	22	"	1/8	1/8	50	20	50	"	11 7/16 "
Benj. Atha . .	"	23	"	1/8	1/8	50	20	50	good	11⅝ "
T.W.B. 0·3 . .	"	24	"	1/8	1/16	70	20	70	"	16½ "
Benj. Atha . .	"	25	"	1/8	1/16	55	3¼	—	gone	2 1/16 "

* Examination of tool showed that it failed long before end of test.
† Point of tool red-hot for 13 minutes.
‡ Point of tool red-hot for 15 minutes.

CHEMICAL COMPOSITION OF ABOVE FORGINGS.

	Bar No. 7238 C′	Bar No. 19788 B′	No. 1506 A
			Total 3·854
Carbon . . .	·876	·105	Graphite 2·948
			Combined ·906
Manganese	·62	·36	·43
Silicon . .	·24	·025	·98

Phosphorous	.025	.023	.298
Sulphur	.028	.035	.055

ANGLES OF TOOLS TESTED.

	Hard Bar.	Soft Bar.	Cast-Iron.
Clearance	6°	6°	6°
Front rake	5°	8°	14°
Side rake	9°	12°	18°

The above table shows the data just as we obtained it, an explanation of forgings, numbers, etc., being given below. It must be understood that all the tools compared with the Taylor-White in these tests were tools that were on the market at the time of the invention. We will consider later various treatments that have come into existence since the Taylor-White patents were granted.

An examination of the tests on the 86° C. hammered forging shows that the relative efficiency of the treated tool and best untreated tool is 11 to 3 or more than 3·5 to 1, for the soft forging (10 carbon) 156 to 70 or 2·2 to 1, and for the cast iron 70 to 55 or slightly less than 1·3 to 1. These figures show that for steel the efficiency is much greater for hard forgings than for soft, but even in the latter case exceeds two to one, while as we might expect the saving on cast-iron is much less, being about $1\frac{1}{4}$ to 1. On hard castings, however, the gain is much more, often reaching 2 to 1, and on this account it is well adapted to certain work. In proof of the latter statement we might add that at the Link-Belt Engineering Company's Works, Nicetown, hard-sprocket wheels can be bored at more than double the speed with Taylor-White tools.

There were many points of interest in the above tests for any one who was not familiar with the operation of treated tools working on low-carbon steel. Reference to the table shows a cutting speed of 156 feet per minute, with $\frac{8}{16}$-inch depth of cut and $\frac{1}{16}$-inch feed. This tool was removing metal at the rate of 353 pounds per hour and was *red-hot* $\frac{5}{16}$ inch from the point. The color was distinctly visible in the daylight, no stronger proof being needed of the high heat at which these tools maintain their cutting edge. At the end of twenty minutes the edge of the tool was carefully

examined with a magnifying glass and found to be *perfect*. In fact, the original grinding-marks could still be detected; consequently, we see that the claims made by the inventors regarding increased efficiency for roughing work are just, so far as the brands of steel we compared are concerned. The importance of this discovery can scarcely be overestimated when we consider how its influence is felt in every establishment where cutting tools are used.

If the manufacturer is doing a large proportion of roughing, it may be the means of doubling his output, assuming that he has already been using the best-known steel. The discoveries of Messrs. Taylor & White, coming, as they did, at a most opportune time, have been an epoch in machine practice, and have simply proved again that scientific methods lead to much better results than guess-work. The great interest which their work awakened in the engineering world was largely due to Mr. Taylor's system of controling the men at Bethlehem Steel Works, which made it possible to run every machine to a much higher efficiency than has heretofore been thought of. We also feel that the Taylor-White steel has done more for a certain class of machine design than any other thing we can point to. It is no longer desirable to have close-speed regulation, etc., but absolutely essential if maximum output is desired. The entire problem has become one of scientific study instead of guess-work, and it is to such work as that followed out by Messrs. Taylor & White that we must look in the future.

In another part of this report reference was made to treatments which have been put on the market since the Taylor-White patents were issued. Several manufacturers of tool-steel claim to have a tool that gives results quite equal to the Taylor-White, and it was our desire to have such tools entered in the above test.

As several of the manufacturers object to making them at the Bethlehem Steel Works, it was deemed best to postpone these trials until a later date, when they can be made at the Link-Belt Engineering Company on a lathe especially adapted to this work and which they expect to have in oper-

ation in a few weeks. If such a series of tests are made it will, of course, be necessary to prove that the various tools do not infringe the patents we are considering.

In conclusion, your sub-committee takes pleasure in recommending the award of the Elliott-Cresson Medal to Messrs. Taylor & White for the discovery and development of a method of treating a certain composition of tool-steel which has made it possible to largely increase the output of machines doing roughing work.

Adopted April 11, 1902.

Attest: WM. H. WAHL, *Secretary.*

ABRAM S. HEWITT.

It is given to few men to do so many things in this world—and to do them so well—as Abram S. Hewitt. An engineer of marked ability; a shrewd and far-sighted business man; a manufacturer who in fifty years never had a strike to contend with; the practical head of a great educational institution; the executive of a great city, the integrity of whose motives was never questioned; a legislator whose opinions on public questions were always heard with respect; above all, a citizen who was ever ready to aid in any movement in the public interest; he leaves a record which must command universal respect, and which may well be studied by younger men. He fully earned the title given him by one of his friends—the "first citizen of New York."—*Electrical World.*

NEW CHEMICAL COMPOUND.

The aluminate of magnesium is a new product which M. Emile Dufour has succeeded in obtaining. An account of the method used has been presented to the Académie des Sciences. In an electric furnace, using a powerful arc of 1,000 amperes and 60 volts, is heated a mixture of 100 parts of alumina and 230 of oxide of manganese, the heat lasting for three minutes. In this way is obtained a porous mass of a brownish-black color, with a metallic reflection. When broken, it presents an irregular surface which is of a fine light-green color and shows a number of geodes of a brown color, lined with brilliant crystals of the octahedral system. To separate the compound, the material is broken and treated with hydrochloric acid; gases are given off and the liquid takes a brown tint, which changes gradually to a light yellow. A crystalline deposit is thus obtained, which is still further purified and analyzed; its composition corresponds to the formula Al_2O_4Mn. The aluminate of magnesium has the form of small transparent crystals of a light yellow color, having the appearance of octahedra, but somewhat modified on the angles. Their density at 20° C. is 4·12. This body is harder than quartz, and its powder is of a light-yellow color. It is quite stable under ordinary conditions, but oxidizes easily when heated in air. At a red heat it

gradually changes color to a dark brown, becoming somewhat lighter upon cooling. In oxygen this oxidation, which was before only superficial, is more rapid and takes place below a red heat. Fluorine attacks it with incandescence at a red heat, but it is not acted upon by bromine, iodine or sulphur. It is insoluble in hydrochloric acid, but is easily attacked by nitric and hydrofluoric acids, and especially by sulphuric acid. Oxidizing agents, such as chlorate and nitrate of potash in fusion, and also the alkaline oxides or carbonates, decompose it easily.—*Scientific American.*

FRESH INTEREST IN TIN MINING.

The one metal absolutely necessary in the production of staple manufactures which has not been produced in this country to any extent is tin. Attempts have been made quite frequently to develop the deposits of this metal which have been discovered in various sections of the United States, but in almost every instance the deposits have either proved too lean to work satisfactorily, or the companies undertaking the problem of conducting operations have not had sufficient capital. It is interesting to note that renewed attention is now being displayed in this direction. Companies have been formed for operating in South Dakota and Southern California, and they are announcing with confidence that they have not only satisfactory deposits of tin ore, but that sufficient capital has been secured to enable operations to be successfully prosecuted. It is to be hoped that the expectations entertained by these companies will be realized, and that this year may see tin produced on a commercial scale in the United States. This country is the largest consumer of tin in the world, and it would be decidedly beneficial to the consuming interests if this essential metal could be produced at home.—*Iron Age.*

CAR AND LOCOMOTIVE STATISTICS FOR 1902.

Returns received direct from practically every locomotive and car-building plant in the country show that approximately 164,547 cars have been built in 1902, including cars for use on elevated railroads, but exclusive of street and other electric cars. This is considerably the largest record which has ever been made in the country and exceeds by 25,542 cars the output for 1901. These figures do not include cars built by railroads at their own shops. Of the cars recorded approximately 162,599 are for freight service and 1,948 for passenger service; 161,747 are for domestic use and 2,800 are for export. In 1901 the total number of cars built was 144,267, which exceeded by 20,161 the recorded output for the year 1900. The 1901 figures included also 5,262 street cars. Almost all of the figures for both 1902 and 1901 are official. The proportion of steel cars and cars with steel underframes to wooden cars will be published in a subsequent issue. It may be interesting also to note that 5,571 cars were built during the year by three firms in Canada.

During the year 4,070 locomotives were built at the various locomotive plants in the country, against 3,384 in 1901. This figure is official throughout and required no estimating. The number for 1902 includes seventy-four electric locomotives. The real meaning of this figure is perhaps best realized by calculating the expenditure involved, which would be nearly $48,000,000. —*Railroad Gazette.*

PHYSICAL SECTION.

Stated Meeting held February 27, 1901.

On the Mathematical Theory of the Geometric Chuck.

By E. A. Partridge, Ph.D.

The cycloid, so important in the history of mathematics, was invented by Galileo in 1590 and named by him as early as 1598. The great mathematicians of the seventeenth century threw all their energy into the task of discovering its properties.

To determine its area, Galileo cut out a cycloid and its generating circle and weighed them. He drew the conclusion that the cycloid has an area very nearly three times the area of the generating circle. This story is given by Torricelli in a letter to Mensenne written in 1643.

In 1658 Pascal wrote a history of the roulette, as the cycloid was called in France. In this work he attributed the invention of the curve to Mensenne and accused Torricelli of intentionally claiming for himself the discovery of results that had previously been obtained by Roberval. A careful study of the whole question has lead Cantor to the conclusion that the charges against Torricelli were erroneous. Pascal contributed greatly to the work of unraveling the properties of the cycloid. Roberval and Wallis each wrote treatises on it, and Descartes, Fermat, Huygens and Wren made important contributions to the growing mass of information concerning this marvelously attractive curve, which, as Chasles says, is connected with nearly all the advances made in mathematics during the seventeenth century.

Curves, such as are considered in this paper, were first conceived by Albrecht Dürer who, in 1525, described what he called the "Spinnlinie," a curve generated by a point moving in a circle about a point itself moving in a circle. He was the first to figure epicyclic curves. More complicated curves than those just described were also conceived by Dürer. He considers curves generated by a point moving

in a circle about a point moving in a circle about a point moving in a circle; in other words, curves resulting from the superposition of several circular motions. They were probably considered by him on account of their ornamental character. However, as Mr. Procter points out, the invention of epicyclic curves should be attributed to the ancient astronomers and particularly to Ptolemy who used some of the properties of such curves in explaining the apparent motions of the moon and planets. But Ptolemy nowhere states anything concerning the shape of an epicyclic curve.

The application of the epicycloid in the construction of the teeth of gear wheels has been ascribed to both Desargues and Roemer.

The mechanical description of epicyclic curves was first accomplished by Soardi, an Italian count, by means of an instrument which he called the "Geometric Pen." This geometric pen was described by him in a work, the substance of the title of which is "On a new instrument for drawing many curves both old and new, which can serve for speculative and practical geometry." This work appeared in 1752. The geometric pen seems to have been limited to drawing curves resulting from the composition of two circular motions. About 1817 Ibbetson devised what he called a geometric chuck. This instrument was made to be used in connection with a lathe.

Perigal and others have from time to time introduced improvements in the construction and arrangement of the chuck. The action of the machine has been carefully studied by Perigal, but in a purely mechanical way. So far as I am aware, no mathematical treatment of the geometric chuck has hitherto appeared.

The geometric chuck is an apparatus which traces curves that result from the superposition of circular motions. In this description of the chuck all mechanical details will be omitted, only the results obtained by the action of its component parts being attended to.

The action of the chuck is as follows:

A plane AB, *Fig. A*, rotates about a fixed center A, a second plane CC' rotates about the center B which is at the same

time rotating about *A*. A third plane *DD'* rotates about the center *C* which is rotating about *B*. A fourth plane *EE'* rotates about *D* which is at the same time rotating about *C*. A fifth plane *GG'* rotates about *E* which is at the same time rotating about *D*. To the fifth plane *GG'* is fastened a piece of paper upon which the pen at *F* traces a curve. Ordinarily the pen is fixed, but it can be given a circular or simple harmonic motion, thereby still further complicating the figure.

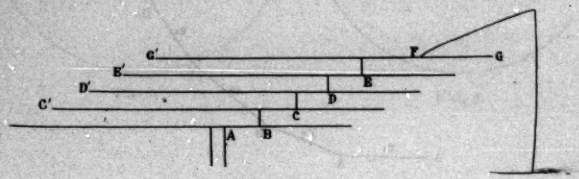


FIG. A.

The above is the actual arrangement.

The distances between the several centers of rotation, viz., *AB*, *BC*, *CD*, *DE* and *AF* are all adjustable, as are also the relative angular velocities. These latter can be direct or retrograde. Since the curve is traced by the fixed pen and movable paper the relation between the tracing point and the center *A* is different from the relations between the other centers of rotation; it is necessary for the symmetry of the mathematical treatment that the relation should be made the same.

The latter requisite is accomplished by inverting the chuck in the following fashion. This is the actual arrangement of the geometric pen:

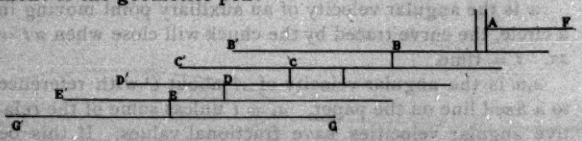


FIG. B.

G' G, *Fig. B*, is regarded as fixed. The plane *EE'* rotates about *E*, the plane *DD'*, about the point *D*, *CC'* about *C*, *BB'*

about B, the line AF about the point A. The curve traced by F is the same as the curve traced on the movable paper by the fixed pen [F (*Fig. A*)] in the actual arrangement.

A method of approach particularly adapted for mathematical treatment is the following:

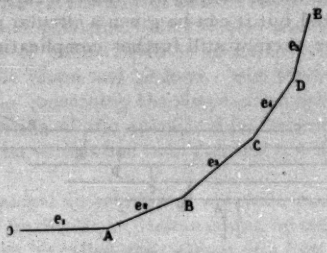


FIG. C.

O, *Fig. C*, is a fixed center round which A revolves carrying B, C, D and E, at the same time as A is revolving about O, B is revolving about A and C about B, D about C, E about D. The path traced by E is a geometric chuck curve.

The following is the notation adopted:

$$e_1 = OA$$
$$e_2 = AB$$
$$e_3 = BC$$
$$e_4 = CD$$
$$e_5 = DE$$

All adjustable but constant during the tracing of any curve considered in this paper.

w is the angular velocity of an auxiliary point moving in a circle, the curve traced by the chuck will close when $wt = 2\pi$. t = time.

$a_1 w$ is the angular velocity of A about O with reference to a fixed line on the paper. $a_1 = 1$ unless some of the relative angular velocities have fractional values. If this be the case a_1 is the least number that will make all the coefficients of w integers.

v_1 is the ratio between the angular velocity B about A

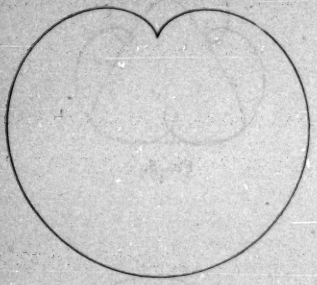


FIG. 1.

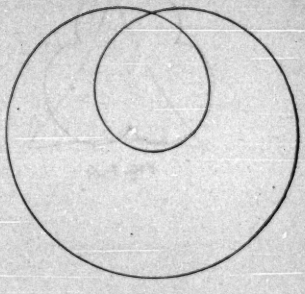


FIG. 2.

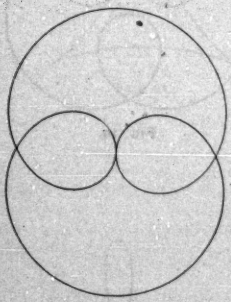


FIG. 3.

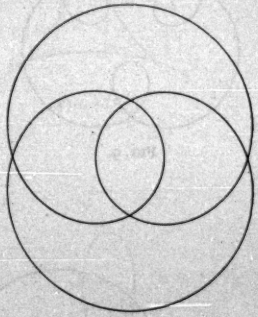


FIG. 4.

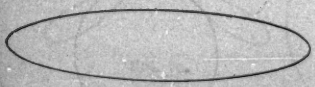


FIG. 5.

FIG. 6.

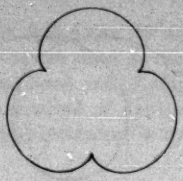


FIG. 7.

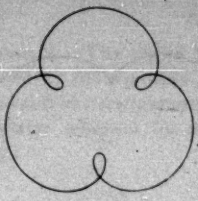


FIG. 8.

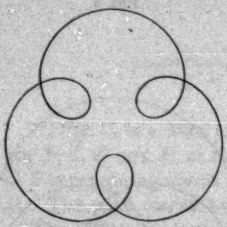


FIG. 9.

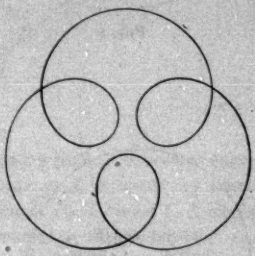


FIG. 10.

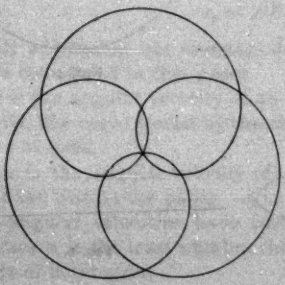


FIG. 11.

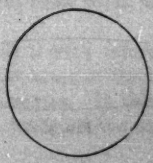


FIG. 12.

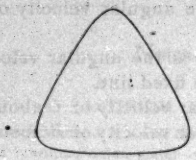


FIG. 13.

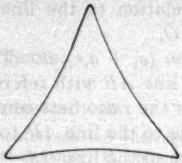


FIG. 14.

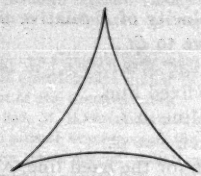


FIG. 15.

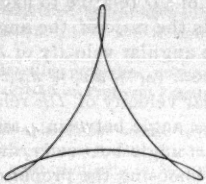


FIG. 16.

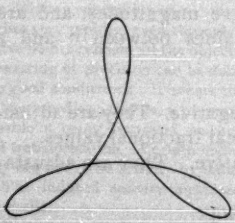


FIG. 17.

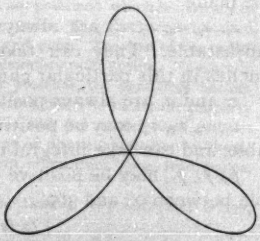


FIG. 18.

with relation to the line OA, to the angular velocity of A about O,

$a_2w = (a_1 + a_1v_1)\,w$. That is, a_2w is the angular velocity of the line AB with reference to the fixed line.

v_2 is the ratio between the angular velocity of C about B relative to the line AB, to the angular velocity of B about A relative to the line OA.

$a_3w = (a_1 + a_1v_1 + a_1v_1v_2)\,w$ is the angular velocity of the line BC with relation to the fixed line.

v_3 is the ratio of the angular velocity of D relative to BC to the angular velocity of C relative to AB.

$a_4w = (a_1 + a_1v_1 + a_1v_1v_2 + a_1v_1v_2v_3)\,w$ is the angular velocity of CD relative to fixed line.

v_4 is the ratio of the angular velocity of E relative to CD to the angular velocity of D relative to BC.

$a_5w = (a_1 + a_1v_1 + a_1v_1v_2 + a_1v_1v_2v_3 + a_1v_1v_2v_3v_4)\,w$ is the angular velocity of DE relative to fixed line.

p_1 = angle between e_1 and fixed line at $t = O$.

p_1 = angle between e_2 and e_1 when $t = O$.

By choosing the proper direction for the fixed line, p_1 and p_2 may always be made $= O$.

p_3 = angle between e_3 and e_2 when $t = O$

p_4 = " " e_4 and e_3 " $t = O$

p_5 = " " e_5 and e_4 " $t = O$

Concerning these quantities the following remarks are to be made:

e_1, e_2, e_3, e_4, e_5, are always positive magnitudes, and are adjustable. They can take all values between 0 and 2 inches in this particular chuck.

w and a_1 are always positive.

v_1, v_2, v_3, v_4, may be positive or negative. They are adjustable, and can take integral or rational fractional values.

p_3, p_4, p_5, may be positive or negative. They are adjustable between 0° and 360°.

[*To be concluded.*]

Notes and Comments.

ACTINIUM, POLONIUM AND RADIUM.

In 1898 Madame P. Curie discovered in pitch blende and chalcolyte (two ores of uranium) a new metal—polonium. Subsequently, M. Curie, Madame Curie and M. Bémont determined another element—radium. In 1899, M. Debienne characterized a third simple body—actinium. The extraction of these metals is not only quite delicate, but long and costly To give an idea, it is sufficient to say that about 0·10 gram of radium chloride is found per ton of ore; that is to say, the residue of the extraction of uranium.

Radium resembles barium closely; its high atomic weight, 175, assigns for it a place in the elements of high atomicity in the Mendéelef tables. Polonium resembles bismuth closely and is precipitated by hydrogen sulphide. Actinium is precipitated by ammonium sulph-hydrate and is similar to thorium.

These new elements possess extremely interesting properties, among which is that of emitting rays similar to those discovered by Professor Roentgen in the light of the Crookes tubes.

In 1896, M. H Becquerel, in studying phosphorescent bodies, remarked that the salts of uranium and the double salts of uranyl and of sodium, or potassium, emit special radiations having great similarity to the X-rays. These have been called Becquerel rays. The three new metals emit Becquerel rays in enormous quantity, approximately 100,000 times greater than uranium. It seems, also, that uranium owes its property only to the presence of traces of actinium.

The radiations of radium, like cathodic rays, are deviated partly by the magnetic field. Another part is not deviated like the X-rays. The deviable rays are charged negatively.

These rays are not reflected nor refracted nor polarized, which is contrary to the existing conception of all vibratory movements. They discharge electrized bodies very rapidly, even through a covering of glass. The dust of the radio-active bodies renders all the objects of the laboratory radio-active. No electric measuring of precision can be done in their presence, the insulators becoming good conductors. It seems that the radio-activity is an atomic property of these bodies; that is, a property connected with the matter itself and not capable of being destroyed, neither by change of physical state nor by chemical transformation. Certain bodies—zinc, tin, aluminium, brass, lead, paper, may acquire radio-activity by induction.

The induced activity increases with the time of exposure and is lost gradually.

Polonium, actinium and radium so act on certain substances as to render them fluorescent, as zinc sulphides, earthy alkaline and alkaline substances, uranium salts, the diamond, blende, paper, glass, cotton.

Radium possesses the property of being spontaneously luminous. This luminosity is readily observed in semi-darkness, and the light emitted may be sufficient to allow of distinguishing written characters. The most curious fact

is that the light emanates from the whole mass, contrary to what takes place in the case of ordinary phosphorescent bodies, which shine only on the surface previously impressed by the light. In moisture the luminosity is diminished, but on drying it reappears in all its intensity. It is continuous, or at least appears to be so, for at the end of a year it is not sensibly diminished.

Radiferous salts have very interesting chemical and photographic properties, due undoubtedly to their radio-activity. They convert oxygen into ozone, and in general act as powerful oxidants or exciters of oxidation. Thus glass and porcelain, with oxidation of manganese, are colored violet under their influence. The chlorides of sodium and of potassium are colored strongly, the latter a deep blue. The rays exert an energetic action on photographic plates, even through opaque bodies, and produce radiographs—less distinct, however, than those of the X-rays.

The applications of these substances may be numerous, provided they can be prepared in appreciable quantity and at lower cost.

Luminous indications might be made on the dials of watches and compasses. The physiological action is not less important. As slow producers of electricity the salts are indicated in the treatment of neuralgia. By application to the temples, and acting on the retina through the flesh, they may serve for diagnosing paralysis of the optic nerve.

Radium was employed in the expedition of M. Paulsen in Iceland for taking the electric tension of the atmosphere, replacing apparatus, complicated and less easy of transportation.

The curious properties of these new metals are for the most part opposed to all accepted mechanical theories, physical and chemical, for they appear to be *spontaneous producers* of light and electricity, in a word, of energy. Now, it cannot be admitted that a body can produce energy indefinitely, however small the production, without borrowing from external sources, and without losing from its mass, and yet this appears to be the case with the three new metals.

According to the measuring of M. and Mme. Curie, the radiating energy is a ten-millionth part of a watt, or expressed in the displacement of matter, about one milligram in a thousand million years.

To reconcile these phenomena with the data of science, different hypotheses have been applied. Thus M. G. Le Bon holds that the energy proceeds from very mobile chemical reactions which may take place successively a great number of times in a very short period, under the influence of simple causes, such as slight variations of temperature. This explanation is perhaps premature, for the knowledge of these bodies is very limited, and nothing yet supports the theory. Is the source of this energy external? It may be supposed that space and material bodies are penetrated with rays of a nature yet unknown and capable of reacting on radio-active substances, so as to produce a secondary emission, manifesting itself in the observed phenomena. On the other hand, it is difficult to imagine electric conductibility in the absence of every material particle; and as these rays are conductors, it may be supposed that there is an ultimate form of very attenuated matter, which these radio-active bodies may be able to emit indefinitely without losing noticeably from their mass. However it may be, the spontaneity of the radiation remains an enigma, a subject of profound astonishment. There is ground for believing

that the discovery of these bodies marks a new stage in the grand history of science, and that it supports the hypothesis of the unity of matter, which has commanded the attention of philosophers for twenty-five hundred years. It is a new step toward the light, and a glimpse may be caught of the moment when the darkness which still envelops so many vast and difficult questions shall be entirely dissipated. Science is yet in its crudest manifestations, and our minds are scarcely trained to grasp the fundamental phenomena which incessant researches are gradually unveiling.—*Scientific Amer. Suppl.*, from the *Revue Chimie Industrielle.*

Book Notices.

Encyclopédie Scientifique des Aide-Mémoire. Librairie Gauthier-Villars, Paris, France.

The following volumes of this encyclopedia have appeared since the last notice of the publication in the *Journal.* Each volume is complete in itself, and the series, which has now reached extensive proportions, embraces nearly the entire field of the applied sciences.

Rabaté (Edmond), Ingénieur-agronome, Professeur spécial d'Agriculture.—L'Industrie des résines. Petit in-8, avec 38 figures.

Defays (J.) et *Pittet* (H.), Ingénieurs civils, Lauréats de la Société industrielle du nord de la France.—Etude pratique sur les differents systèmes d'éclairage. *Gaz. acétylène, pétrole, alcool, électricité.* Petit in-8.

Morel (Marie-Auguste), Ingénieur, ancien élève de l'Ecole des Ponts et Chaussées, licencié ès sciences mathématiques et ès sciences physiques.—Le ciment armé et ses applications. Petit in-8° avec 100 figures. (Broché. 2 fr. 50c. Cartonné, 3 fr.) W.

A Text-Book of Physics. By J. H. Poynting, Sc.D., F.R.S., and J. J. Thomson, M.A., F.R.S., etc. Properties of Matter. London: Charles Griffin & Co., Ltd. Philadelphia: J. B. Lippincott Company. 8vo, vi + 228 pp. (Price, $2.75.)

This volume constitutes properly the first of a series forming a text-book on physics, which is being prepared by these well-known authors.

The present volume treats of the subjects of weight, mass, gravitation and those properties of matter which relate chiefly to change of form, as electricity, fluid viscidity, surface tension, diffusion and solution. W.

Specielle Elektrochemie. Von Dr. H. Danneal. Privat-docent für physikalische Chemie u. Elektrochemie an der k. techn. Hochschule zu Aachen. Lieferung I (large 8vo, pp. 80). Halle a. S. Verlag von Wm. Knapp. 1903. (Price, 3 marks.)

Elektromagnetische Aufbereitung. Von F. Langguth, Bergingenieur. (Large 8vo, pp. 64.) Halle a. S. Verlag von Wm. Knapp. (Price, 3 marks.)

The above-named volumes constitute the earliest contributions to an extensive "Handbuch der Elektrochemie," which is in course of publication by the house of Knapp, under the editorial supervision of such well-known experts as Borchers, Nernst and others.

The work of Danneal is devoted to the special electrochemistry of the elements and inorganic compounds; their production by electrochemical methods and their electrolysis.

Longguth's work is an interesting contribution to the history and application of the methods of magnetic separation and concentration of ores.

W.

Franklin Institute.

[*Proceedings of the Annual Meeting held Wednesday, January 21, 1903.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 21, 1903.

Vice-President WASHINGTON JONES in the chair.

Present, 210 members and visitors.

The annual election held this day resulted as follows:

For President	(to serve one year)	JOHN BIRKINBINE.
" *Vice-President*	(" three years)	THEO. D. RAND.
" *Secretary*	(" one year)	WM. H. WAHL.
" *Treasurer*	(" ")	SAMUEL SARTAIN.
" *Auditor*	(" three years)	W. O. GRIGGS.

For *Managers* (to serve three years).

CYRUS BORGNER, JAMES CHRISTIE, F. L. GARRISON, H. W. JAYNE, JAWOOD LUKENS, LAWRENCE T. PAUL, HORACE PETTIT, OTTO C. WOLF.

(To serve for two years.)

CHARLES LONGSTRETH, WALTON CLARK, LOUIS E. LEVY.

(To serve for one year.)

WALTER WOOD.

For *Members of the Committee on Science and the Arts* (to serve three years).

H. F. COLVIN,	C. C. HEYL,	LUCIEN E. PICOLET,
THOMAS P. CONARD,	H. R. HEYL,	CHAS. E. RONALDSON,
GEO. S. CULLEN,	GEO. A. HOADLEY,	CLAYTON W. PIKE,
CHARLES DAY,	H. F. KELLER,	SAMUEL P. SADTLER,
ARTHUR FALKENAU,	LOUIS E. LEVY,	HENRY LEFFMANN,
J. M. HARTMAN,	TINIUS OLSEN,	W. N. JENNINGS,

ERNEST M. WHITE, RICH'D L. HUMPHREY.

(To serve for two years.)

KERN DODGE, E. GOLDSMITH, WERNER KAUFFMANN, JESSE PAWLING, JR., FRANK ROSELLE.

(To serve for one year.)

ROBERT H. BRADBURY, J. W. RIDPATH,
WM. O. GRIGGS, CHAS. A. RUTTER,
URBANE C. WANNER.

The annual report of the Board of Managers, with appendices embracing the annual reports of the Sections and of the various Standing Committees was presented, and is hereto appended.

Prof. Joseph W. Richards, of Lehigh University, presented a communication, illustrated by specimens and lantern photographs, on the "Aluminum Industry," with particular reference to the contributions of Mr. Chas. M. Hall.

Mr. E. E. Taylor, M.E., of Boston, read a paper describing the "Under-Feed Mechanical Stoking of Steam Generators," with special reference to the Jones Under-Feed Stoker. The speaker illustrated the subject freely with the aid of the lantern. The paper was discussed by a number of members, and the invention described was referred to the Committee on Science and the Arts for investigation and report.

A communication by Mr. H. Armor Ward, on the "Brazing of Iron Castings," was postponed until the next stated meeting on account of the lateness of the evening.

Adjourned,

WM. H. WAHL, *Secretary.*

ANNUAL REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE FOR THE YEAR 1902.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 17, 1903.

To the Members of the Franklin Institute:

In presenting its report for the year 1902, the Board of Managers of the Franklin Institute congratulates the members upon the determination evinced, by personal sacrifice, to maintain the work of the organization, which for nearly four-score years has been a leader in scientific progress.

An increase of the annual dues was often presented to the management, and as often discouraged, to exploit some other suggested method of bettering the financial condition of the Institute.

The Board, while realizing that the Institute offered its members in numerous instructive meetings, discussions and lectures, and in unexcelled library privileges, more than any other technical or semi-technical society, hesitated to recommend an increase of annual dues, equal to those charged by other organizations, until all other means had been tried.

For many years the income of the Institute has been insufficient to support its work properly, and assistance was obtained from exhibitions to supplement the income. But although the Institute originated industrial exhibitions in America, and held numerous successful displays, the magnitude of such functions at the present time involves a financial risk which the Institute cannot assume, and the amended charter requires that all special incomes pass to the Trustees for investment, the interest on which only can be applied to current expenses.

The Institute, bearing the honored name of Franklin is, unfortunately, considered as being a beneficiary of the noted philosopher, whereas not one dollar of Franklin's money came to the Institute.

The organization was perfected years after Franklin's death, and the name was selected because of a desire to honor Benjamin Franklin. It, however, received no benefit from funds resulting from Franklin's investments. In fact, the Institute's small endowment is made up of a number of bequests and gratuities, and the funds at present in the Trustees' hands aggregate only about $60,000.

If such invested funds were sufficient to produce annually a sum which, by supplementing the dues, would properly maintain the work, the financing would be a simple problem. But with a small endowment, most of which is limited in its application and low interest rate, the Institute must rely mainly upon the membership to sustain its work. Consequently, the Board, after mature consideration, recommended to the members a change in the by-law increasing the annual dues, which change was adopted by the Institute after full discussion.

Recognizing the interest thus shown by the members, a fund was raised to make the advanced dues immediately effective by paying all floating indebtedness; and the Board can, for the first time in many years, state that the Institute commences the year free of all indebtedness, except the fund above mentioned, which bears no interest and is an advance from those interested in the organization, which will be repaid from increased revenue, and except the mortgage made to the Trustees to pay for fire-proof library facilities, which is being annually reduced.

As the increase of dues took effect in October last, its permanent effect cannot be noted; but it is gratifying to report that a material increase in income is assured, and that the number of resignations which can be attributable to the augmented dues is less than was expected. Undoubtedly, most of the members have not measured the value of the Franklin Institute merely by the personal use they make of it, but rather by the service it renders the scientific world.

With its record of splendid achievements, the Franklin Institute deserves consideration from some who have surplus wealth to dispense, and it is the hope of your Board that such recognition will be accorded it as will permit of enlarging its field of work, and of carrying forward important investigations. But with the support of its present membership at the increased dues, the functions of the Institute, as now attempted, can be carried on and the expenses met, demonstrating a determination for self-help which should command recognition from others.

Appreciating the interest evidenced by the members in voluntarily increasing the annual dues, the Board of Managers is endeavoring to add to the value of membership by more closely limiting the privileges to non-members. This is not, or will not be done, to restrict the general usefulness of the organization, but to protect the Institute from those who abused privileges for which they made no return. The Board considers that the library, the lecture courses and other privileges, primarily belong to the members of the Franklin Institute, and its desire is to make this manifest, without in any way limiting the service which should be rendered the public.

Changing conditions demanded, and will continue to demand of the Franklin Institute, modifications in its detailed work. Although it has done pioneer service in establishing technical libraries and publications, scientific and popular discussions, and lecture courses presenting demonstrations of inventions and processes, etc., these valuable features have been copied by various junior organizations, some having liberal endowments, and to maintain its position of pre-eminence demands larger annual expenditures. The increased number of publications requires liberal appropriation to maintain a standard reference library of technical literature, and numerous lecture courses of a popular character require that the Franklin Institute present to its members the best, and the best costs money.

Papers and discussions at conventions of engineering and kindred societies require that the wide field attempted by the Institute be covered by superior papers and discussions at the meetings of the Institute and its Sections.

It has developed and should maintain a special work, much of which is not, or will not be accomplished by other societies or the technical press; but to maintain this work means that the Institute can keep in the van only at a continually increasing cost for maintenance.

That the above is being carried out with credit to the Institute is evidenced by the special reports of its Sections and Committees.

All parts of the Institute building are used for its library, schools, lectures, etc., and the congested condition of some portions emphasize the necessity for a new building.

In the work of the Committee on Science and the Arts, the Franklin Institute stands alone, and its medals and awards are eagerly sought for. Of the 108 cases before this Committee, fifty-two were disposed of and twenty-two medals, or awards, allotted. The gratuitous service which members of the Franklin Institute render through this Committee, to inventors and others, is of incalculable value, and the thoroughness of the investigations, and the equity of the awards, are evidenced by the small number of protests made. Errors have been or will be committed, but the safeguards thrown about the investigations and discussions, and the opportunity given for protest before an award is effective, minimize the risk of this important service, rendered without demand or expectation of return.

The demands on the members have been so great that, upon the recommendation of the Committee on Science and the Arts, its number was increased to sixty, by amendment to the by-laws.

The Board desires to express its recognition of the unselfish work of this Committee and of other Committees of the Institute.

The programs of monthly meetings prepared by the committee in charge have demonstrated the necessity of increased accommodation in our lecture-room, and improved facilities for demonstration and the work of the various sections has also emphasized this deficiency. It is regrettable that papers of such value, and discussions of such importance, must of necessity be prevented under existing disadvantages, or that the Committee on Instruction needs seek accommodations for those who attend its popular lecture courses elsewhere than in the Institute building.

Special attention is directed to the increased attendance reported in the night-schools of the Institute. Six hundred and thirty-nine young men, most

of them employed during the day, sought the privileges offered by the Franklin Institute to advance themselves, and for five nights during the fall and winter the Institute aids these worthy young men, who crowd our limited space to reach a higher and wider field than their present vocation offers.

Three hundred and eighty of these devoted their time to the drawing-school; 134 studied machine design; and our latest effort, the School of Naval Architecture, has 125 enrolled as students. Among these are undoubtedly some who, in future years, will achieve renown which may be credited largely to the facilities which the Franklin Institute has so persistently offered to those who wish to help themselves.

The report of the Library Committee shows a gratifying increase in additions, but repeats its complaint that the funds available are insufficient to properly care for our priceless library, or to add all which the Committee considers desirable.

Realizing the great value of the library, the Board of Managers is desirous of adding to this, and preserving the collection which could not to-day be duplicated.

With sorrow we report that two members of the Board of Trustees died during the year—Mr. Joseph M. Wilson, who for ten years served as President, and Mr. Enoch Lewis, who has for many years been associated with the Institute work. Also Mr. Stacy Reeves, whose active interest in housing our library demonstrated his loyalty to the Institute, was removed from us by death.

Suitable memorials of our departed co-laborers were adopted by the Board and the Institute. By order of the Board.

(Signed) JOHN BIRKINBINE,
President.

APPENDICES.

FINANCIAL STATEMENT FOR THE YEAR 1902.

Balance on hand January 1, 1902	$1,049 96
Receipts	26,614 73
	27,664 69
Payments	27,315 93
Balance	$348 76

REPORT OF THE COMMITTEE ON INSTRUCTION FOR THE YEAR 1902.

To the Members of the Institute.

GENTLEMEN: The Committee on Instruction has nothing to add to its report of the previous year in respect of the popular scientific lecture courses, which have been continued as in previous years in conjunction with the Central Branch of the Young Men's Christian Association. The policy of reserving admittance to these lectures exclusively to the members of the two societies, has caused a considerable decrease in the attendance as compared

with that of former years, but the Committee anticipates that this will be largely overcome by permitting the members of the two societies to receive a limited number of admission tickets for distribution to friends.

The services of lecturers, as heretofore, have been given gratuitously, and the thanks of the Institute are due all who have contributed to this branch of its work.

With reference to the operations of the schools, the Committee was able in its previous report to note a substantial increase in the number of pupils. The year 1902 exhibits even more gratifying evidence of improvement, as the following figures will disclose:

	1901.	1902.	Increase.
Drawing School	299	380	81
School of Machine Design	80	134	54
School of Naval Architecture	97—476	125—639	28
Total increase			163

Respectfully submitted,

WM. H. WAHL,
Chairman of Committee on Instruction.

PHILADELPHIA, January 1, 1903.

ANNUAL REPORT OF THE COMMITTEE ON PUBLICATIONS FOR 1902.

To the Members of the Institute:

Your Committee on Publications has nothing special to record respecting its operations during 1902, and wishes simply to reiterate the general statements contained in its report for the previous year.

THEODORE D. RAND,
PHILADELPHIA, January 14, 1903. *Chairman.*

ANNUAL REPORT OF THE COMMITTEE ON ELECTION AND RESIGNATION OF MEMBERS FOR THE YEAR 1902.

To the President and Members of the Franklin Institute:

The Committee on Election and Resignation of Members, by direction of the Board, has revised the list of members, and eliminated therefrom the names of a large number of life members whose addresses have been for many years unknown, and who are believed to be deceased, though the Institute has not been authoritatively so advised. The membership at the close of 1902, after such revision and the usual deductions on account of death, resignation and non-payment of dues, is 1,771. ALEX. KRUMBHAAR,

January 1, 1903. *Chairman.*

ANNUAL REPORT OF THE COMMITTEE ON SECTIONAL ARRANGEMENTS FOR THE YEAR 1902.

To the Members of the Institute:

The Committee on Sectional Arrangements is pleased to transmit herewith the report of the operations of the six Sections of the Institute, giving details of the scientific and technical work accomplished by those bodies during the past year.

The Committee is much gratified to be able to report that the activity of the Sections continues unabated, and that both in the number of the communications contributed by them, and in character, the Section work is most creditably maintained.

JAMES CHRISTIE.
January 1, 1903. *Chairman Com. on Sectional Arrangements.*

(Appendix embracing the operations of the Chemical Section, the Electrical Section, the Mining and Metallurgical Section, the Mechanical and Engineering Section, the Physical Section and the Section of Photography and Microscopy.)

To the Committee on Sectional Arrangements.

GENTLEMEN: During the past year a radical change was introduced in the manner of holding the meetings of the Sections. Instead of holding separate monthly meetings as heretofore, the Sections, on the recommendation of their respective Executive Committees, have been meeting in joint session on Thursday evening of each week.

The plan was promoted principally for the reason that the communications presented frequently interested the members of several Sections, and it was deemed expedient to give all the Section members the opportunity of attending these meetings.

The plan has worked well in practice, and has had the added advantage of considerably increasing the attendance, which has been much above the average attendance of previous years.

It has also been decided by separate action of the Sections to ask the Committee on Sectional Arrangements to name an Executive Committee for each Section to conduct its necessary business affairs, appoint officers, etc., thus simplifying their administration.

The general efficiency of the Sections has been maintained in a very satisfactory manner. The number of communications presented at the meetings has been large, and their character, as a rule, of a high order of excellence, and they have provided the Committee on Publications with an abundance of acceptable material for the *Journal*. . . .

WM. H. WAHL,
for the Secretaries.

ANNUAL REPORT OF THE LIBRARY COMMITTEE FOR 1902.

To the President and Members of the Franklin Institute.

GENTLEMEN: The Committee on the Library respectfully reports the following summary of the operations of the Library during the year 1902:

Bd. Vols.	Unbd. Vols.	Pphs.	Chts.	Phts.	Mss.	Clippings.
890	277	836	1	18	1	1

Total for the year 2,024

A decrease of 11 from 1901, and of 1,385 from 1900.

Total number of volumes, January 1, 1903 54,529

Total number of pamphlets, January 1, 1903 38,727

The Library also contains 2,456 maps and charts, 659 drawings and designs, 1,243 photographs, 192 newspaper clippings, 31 manuscripts.

Bound during the year 419

Exchanges.—There are now 523 societies and publications on the exchange list of the *Journal*—an increase of 11 over 1901.

The additions to the Library are again fewer than for any one of the last twenty years, owing mainly to the continued uncertainty of the income. The Moore Fund, ordinarily yielding about $750 yearly, the Lea Fund about $150 yearly, and the Memorial Library Fund about $50 yearly, have in the past year supplied but few books; but the James T. Morris Fund, about $100 a year, has begun to yield a number of volumes. The funds, however, have now begun again to produce their usual income.

The daily number of visitors to the Library has much diminished, in consequence of the Board of Managers' instructions to be strict about granting the privileges of the Library to those not entitled to them. The hope has been that thereby the usefulness of the Library may not be lessened, while the presence of idlers is discouraged, and others are led to appreciate more highly the privileges of membership. There is an increased number of evening visitors, under a recent re-arrangement of the hours, whereby the Library is open until ten o'clock on Tuesday and Thursday evenings, as well as the Wednesday evening of the monthly meetings of the Institute.

The binding is still deplorably backward and there is great need of binding at once about 500 volumes at an expense, now, of about $500. After that about $300 a year would cover the cost of binding the serial publications as fast as the volumes are completed, saving them from speedy ruin. There are also many volumes of not yet completed sets of periodicals that ought to be bound without further delay, if it were only possible to pay the expense, probably $100. The 372 volumes bound include a portion of the "periodicals of sets not yet completed," besides current periodicals.

The north room of the lower floor has been in satisfactory use the past year, and nearly all the shelves put in a year ago are already filled with Congressional Reports. The Board of Managers has now turned over the south room likewise to the Library, and it is used as a storage room for charts, duplicates and completed volumes of periodicals ready to go to the binder. It is highly desirable that the walls should be shelved during the coming year, for the space so given would be useful in many ways.

The large and exceedingly valuable collection of pamphlets has not yet found space on the shelves in these lower rooms, and still needs arranging and complete cataloging. The need of an additional assistant for this work is extremely pressing; and, as mentioned last year, the same assistant could give the much-needed closer attention to following up the collection of the numerous municipal and governmental serial publications of great engineering value, and countless useful trade catalogues.

The valuable collection of United States Geological Survey maps are still sorely in need of a suitable case of shallow drawers, where they would be conveniently accessible without injury from excessive handling. Estimates were obtained for such a case and it was found it would cost $125.

The crying needs of the Library, outside of the ordinary expense for the coming year, for binding, for completion of the fitting up of the northern room, shelving the walls of the southern new bookroom, an additional assistant, map case, and certain much-needed books beyond reach of the special funds, demand an appropriation of $2,475.

The members of the Library Committee still maintain untiring zeal in the interest of the Institute.

BENJAMIN SMITH LYMAN,
PHILADELPHIA, January 12, 1903. *Chairman Committee on Library.*

REPORT OF THE COMMITTEE ON MEETINGS FOR THE YEAR 1902.

To the President and Members of the Franklin Institute:

Your Committee on Meetings has provided for the ten monthly meetings prescribed as its duty, and believes that in general interest the meetings of the past year will compare favorably with those of former years. The best evidence of this fact is to be found in the figures of attendance, and in this respect the Committee is pleased to be able to report a notable increase.

WASHINGTON JONES,
January 1, 1903. *Chairman Committee on Meetings.*

ANNUAL REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS FOR THE YEAR 1902.

HALL OF THE FRANKLIN INSTITUTE.

To the President and Members of the Franklin Institute:

The following report of the Committee on Science and the Arts is respectfully submitted:

The number of cases pending on December 31, 1901, was		47
The number of new cases proposed in 1902 by application was	31	
By reference from Institute	6	
By reference from Sections	1	
By vote of the Committee	24	
Total number of new cases in 1902	62	
Total number of cases before Committee in 1902		109
Number of cases acted upon	51	
of which there are pending, 7. withdrawn, 2.		
Finally determined	52	
Cases pending December 31, 1902	57	
		109

The fifty-two cases completed were determined as follows:

Award of Elliott Cresson Medal	2
Award of John Scott Premium and Medal	12
Award of Edward Longstreth Medal of Merit	8
Award of Certificate of Merit	4
Reports without award	5
Carried forward	31

Brought forward	31
Reports advisory	11
Cases withdrawn	2
Cases dismissed	8
Total	52

During the past year, the recommendation of the Committee that the By-laws of the Institute be amended so as to permit of the increase of the membership of the Committee from forty-five to sixty, was carried into effect. Sufficient time has not yet elapsed to permit all the advantages of this increase of working force to be fully realized, but these will, no doubt, be very apparent in the coming year.

The directions of the Institute for the issue of diplomas with the medals awarded by the Committee were also carried into effect, a very liberal arrangement with the American Bank Note Company and the Board of Directors of City Trusts having enabled the Committee to provide practically the entire cost of the engraving without calling on the Institute to furnish the funds for the purpose. The diplomas, which are most artistically designed and well executed are now ready for issue to the recipients of the medals; and they will doubtless add materially to the publicity of the Institute's awards and increase their usefulness.

From the preceding summary statement of the Committee's operations, it will appear that the amount of work accomplished during the past year slightly exceeded that of the year 1901. The number of cases submitted for investigation, however, considerably exceeded the number of the previous year, and the number of cases pending on the Committee's Record Book is also considerably greater. In fact, the Committee members, even with the enlarged numbers, have as many assignments for Committee duty at present as they can properly care for.

THOS. P. CONARD,
Chairman Committee on Science and the Arts.

PHILADELPHIA, January 1, 1903.

Committee on Science and the Arts.

(*Abstract of proceedings of the stated meeting held January 7, 1903.*)

MR. THOS. P. CONARD in the chair.

The following reports were adopted:

(No. 2222.) *Theory of Musical Harmony.*—Dr. Victor Goldschmidt, Heidelberg, Germany.

This report is reserved for publication in full. The Elliott Cresson Medal is awarded to applicant. [*Sub-Committee.*—Dr. Joseph W. Richards, Chairman; E. Goldschmidt, J. Fred. Wolle, C. C. Heyl, G. A. Hoadley.]

(No. 2229.) *Hydrocarbon Burner.*—C. Francis Jenkins, Washington, D. C.

(An advisory report.)

(No. 2248.) *Photo-polychrome Printing Process.*—Henri Bürger, Zürich, Switzerland. Reserved for publication in full. The award of the John Scott Premium and Medal is recommended to the inventor. [*Sub-Committee.*—Louis E. Levy, Chairman; Samuel Sartain, Max Rosenthal, W. N. Jennings].

(No. 2257.) *Blue-Printing.*—Pittsburgh Blue Print Co., Pittsburgh, Pa.

ABSTRACT.—The improvement embraces an apparatus devised by Samuel Brent Whinery, of Pittsburg, intended for the production of blue-prints, and is designed to facilitate the manipulation of cylindrical glass-printing frames in the process of photographic printing by electric light on paper or other flexible material sensitized for the purpose, through a flexible negative or positive, such as a drawing on transparent material or a photographic film stripped from its glass support.

The apparatus, in general terms, may be described as consisting of the above-named glass cylinder, made of two longitudinal halves, which is adapted to receive the transparency and sensitized paper on its entire surface, and an electric arc-lamp arranged to move up and down through the upright cylinder, and having its speed controlled by suitable mechanism.

The essential features of this apparatus, namely, the substitution of a cylinder of glass in place of the ordinary flat-printing frame, the application of an electric lamp moving through the axis of the cylinder, and the determination of the time of exposure by a measured movement of the source of light have long been in use, and are not claimed as new.

The novel features presented in the present arrangement are, first, a method of securing two flap covers tightly around the outside of the semi-cylinders over the transparency and paper by means of specially devised holders on one of the uprights of the frame, and of spring catches to fasten the free end of the flaps to the upright on the opposite side; second, a carbon holder for the electric lamp adapted to permit the lower carbon to be rotated on its axis for proper adjustment in relation to the upper one, and, third, an escapement mechanism for adjustively regulating the descent of the lamp in the cylinder, and correspondingly determining the deviations of the exposure. These devices are each covered by letters-patent numbered 699,355, 702,514 and 704,415, dated, respectively, May 6, June 17 and July 8, 1902.

In consideration of the improvements embodied in these devices the Certificate of Merit is awarded to the inventor. [*Sub-Committee.*—L. E. Levy, Chairman; Samuel P. Sadtler, Chas. E. Ronaldson, Martin I. Wilbert.]

(No. 2247.) *Dirt Eradicator for Trolley Lines.*—Henry C. Mayer, Blooming Grove, Pa. (An advisory report.)

First reading.

(No. 2230.) *Speed Controller.*—Consolidated Machine Specialty Company, Boston, Mass.

(No. 2249.) *Magnetic Clutch.*—Bion J. Arnold, Chicago, Ill.

(No. 2250.) *Multiple Unit System of Electric Traction.*—Frank J. Sprague, New York.

(No. 2267.) *Apparatus for Measuring and Recording the Variable Diameter of Tubes.*—L. Bancroft Mellor, Philadelphia.

(No. 2269.) *Horizontal Folding-Door.*—Wm. A. Cross, Chicago, Ill.

W.